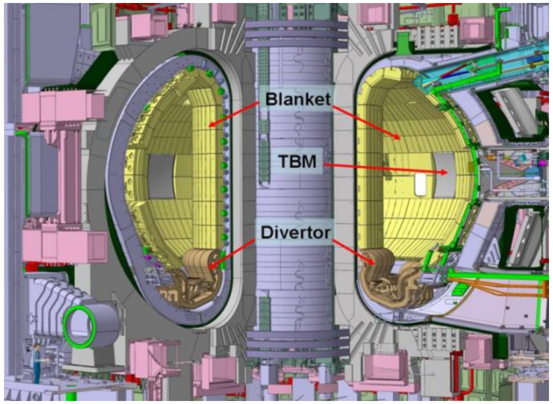

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ITER TBM Program and associated System Engineering

Presented by

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Disclaimer
The views and opinions expressed herein do not necessarily reflect those of the ITER Organization

ITER TBM Program and associated System Engineering

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➔ The presenter wishes also to thank the TBM Teams from CN, EU, KO, JA and IN for the pictures used in this presentation concerning the corresponding Test Blanket Systems.

Preamble

A Fusion Power reactor needs to produce by itself all the Tritium that is needed as fuel for the D-T plasma (Tritium-breeding self-sufficiency) while ITER is using external Tritium source.

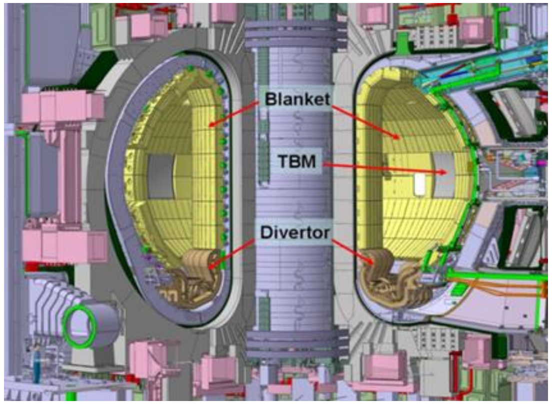
Therefore, one of the ITER missions is the following (cf. Project Specifications):

“***ITER should test tritium breeding module concepts that would lead in a future reactor to tritium self-sufficiency, the extraction of high grade heat and electricity production.”***

All the activities performed by the Central Team of the ITER Organization (IO-CT) & by the ITER Members (IMs) Domestic Agencies (DAs) and related to this mission form the **“ITER TBM Program**”.

Outline of the presentation

1. Introduction
2. Main Features of the six Test Blanket Modules
3. TBM Program Test Plan and Objectives
4. Test Blanket Systems Integration in the ITER Tokamak Complex Buildings and Port Cell Maintenance
5. Main Sub-systems of the Test Blanket Systems
   a. Main Features of Helium Coolant Systems & He-Coolant Purification Systems (Tritium)
   b. Main Features of Water Coolant System
   c. Main Features of some Tritium Extraction Systems
   d. Main Features of Lithium-Lead Systems
   e. Main Features of Instrumentation & Control Systems
6. Summary of the Main TBS Interfaces with other ITER Systems
7. Final Considerations and Conclusions



1 - Introduction

Testing of Tritium Breeding Blankets in ITER

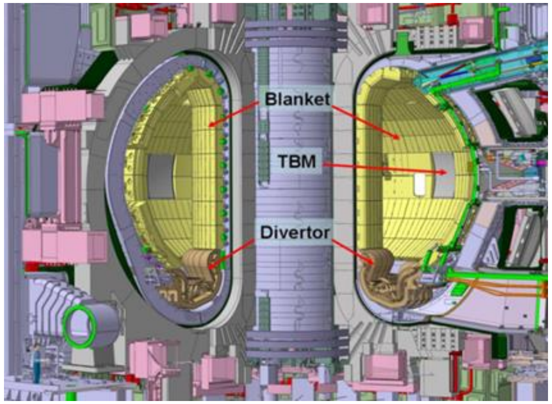
- In a D-T Fusion Reactor, the Tritium Breeding Blankets (TBBs) have the 2 main functions:
  - **producing** all the required **Tritium** fuel,
  - **extracting the heat** for power generation.

  Tritium Breeding Blankets are complex components, compulsory in the "next-step" reactors after ITER, often called DEMO, where they will be submitted to severe working conditions. They are not present in ITER where the needed Tritium is provided by external sources.

- Since Tritium Breeding Blankets are essential components in DEMO, their development is present in all ITER Members Fusion Power R&D plans.

- ITER is a unique opportunity to test TBB mock-ups in DEMO-relevant conditions and in an actual tokamak environment:

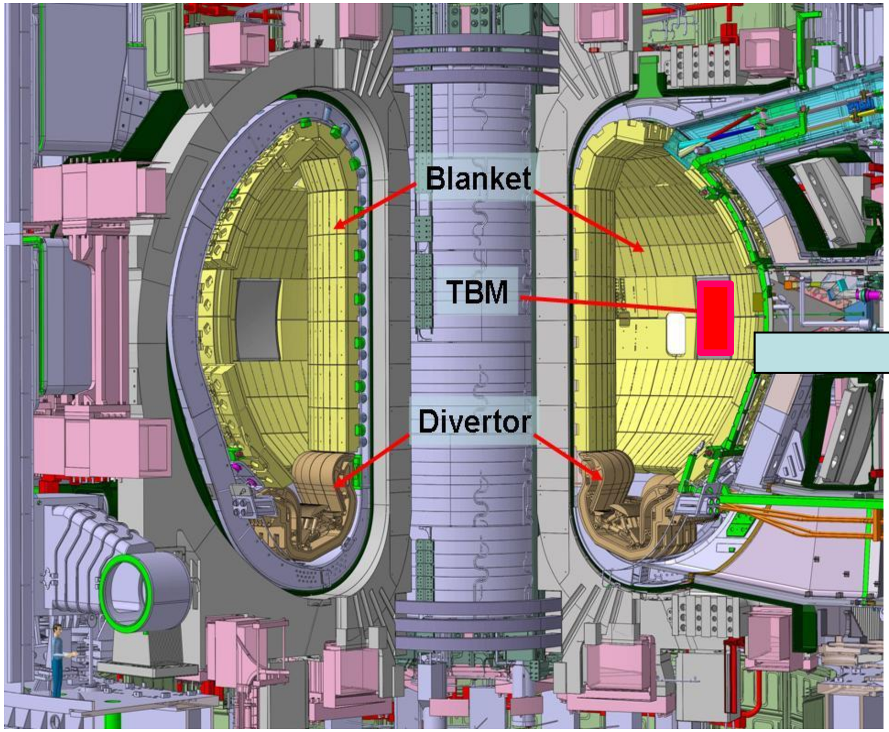
  ➔ **Test Blanket Modules (TBMs) and associated Systems**

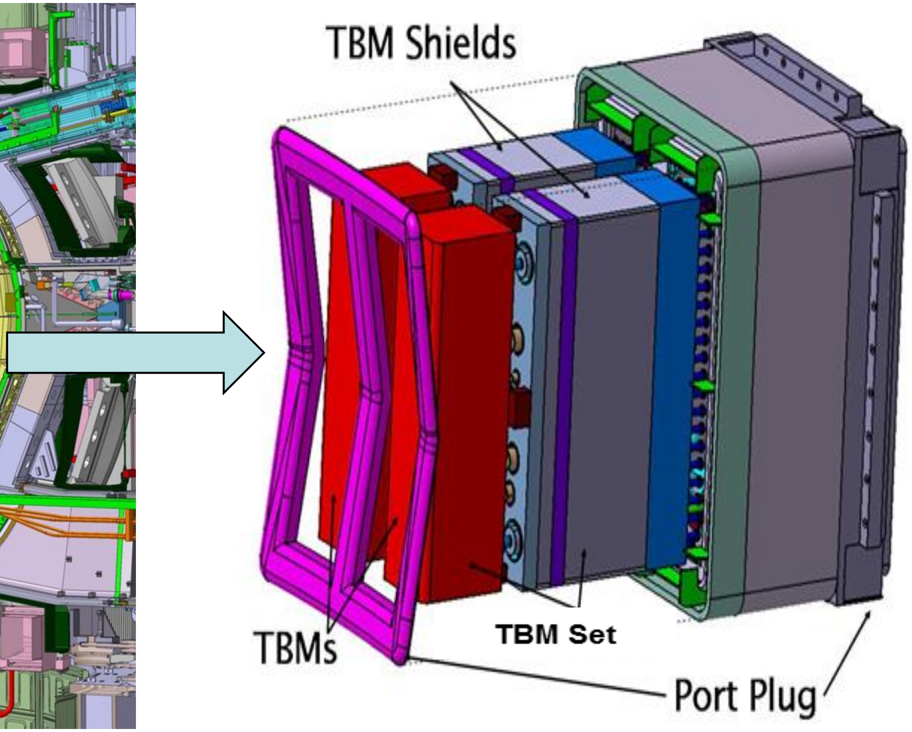


2 - Main Features of the six Test Blanket Modules

Boundary Conditions in ITER for TBMs testing

- The **"ITER TBM Program"** foresees the operation of **six TBMs**, located in 3 dedicated ITER equatorial ports (2 TBMs per port), with their own ancillary systems (e.g., coolant, purification, Tritium extraction, Instrumentation & Control) to form **six Test Blanket Systems** (TBSs).

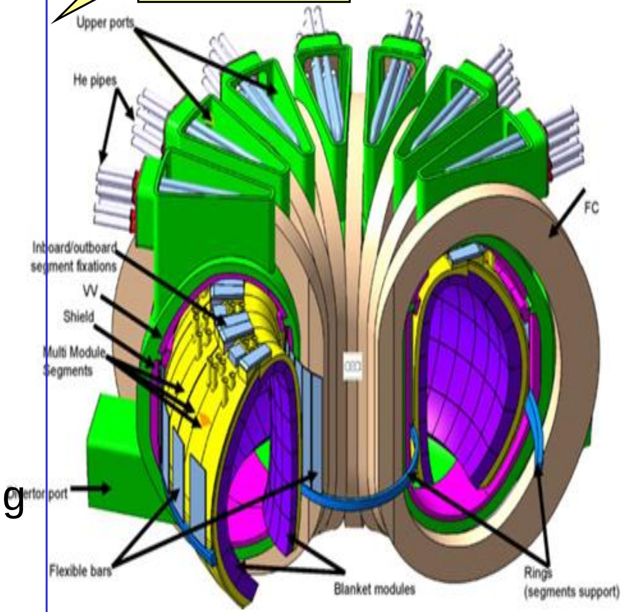




The six mock-ups of DEMO Breeding Blankets selected for being operated and tested in ITER

SOLID Breeders

- ► ***Helium-Cooled Pebble Bed (HCPB)*** concept, using Reduced Activation Ferritic/Martensitic steel (RAFM steel) structures, He-coolant, Be-multiplier, and Li_2TiO_3 or Li_4SiO_4 ceramic breeder: *proposed by EU*
- ► ***Water-Cooled Ceramic Breeder (WCCB)*** concept ,using RAFM steel structures, water-coolant, Be-multiplier, and Li_2TiO_3 ceramic breeder: *proposed by Japan*
- ► ***Helium-Cooled Ceramic Breeder (HCCB)*** concept, using RAFM steel structures, He-coolant, Be-multiplier, and Li_4SiO_4 ceramic breeder: *proposed by China*
- ► ***Helium-Cooled Ceramic Reflector (HCCR)*** concept, using RAFM steel structures, He-coolant, Be-multiplier, Li_2TiO_3 ceramic breeder and C-pebbles reflector: *proposed by Korea*



LIQUID Breeder

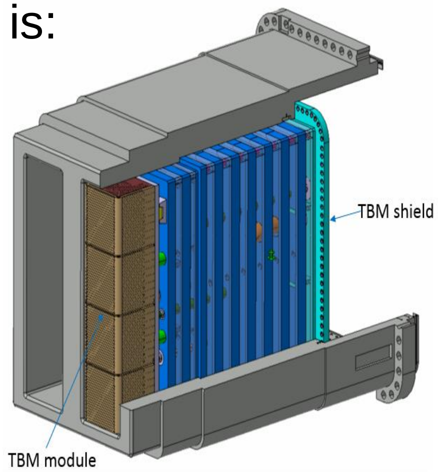
- ► ***Helium-Cooled Lithium-Lead (HCLL)*** concept, using RAFM steel structures, He-coolant, and Pb-16Li breeder & multiplier: *proposed by EU*
- ► ***Lithium-Lead Ceramic Breeder (LLCB)*** concepts using RAFM steel structures, He-coolant , Pb-16Li breeder & multiplier & coolant, and Li_2TiO_3 ceramic breeder : *proposed by India*

Overview of the TBM Program in ITER

Starting from the selected DEMO BB, the TBMs port allocation is:

Port Nb	Fist Concept	Second Concept
16	HCLL (TL : EU)	HCPB (TL : EU)
18	WCCB (TL : JA)	HCCR (TL : KO)
2	HCCB (TL : CN)	LLCB (TL : IN)

(TL = TBM Leader)



HCLL : Helium-Cooled Lithium Lead, **HCPB** : He-Cooled Pebble Beds
WCCB : Water-Cooled Ceramic Breeder, **HCCR** : Helium-Cooled Ceramic Reflector
HCCB : He-Cooled Ceramic Breeder, **LLCB** : Lithium-Lead Ceramic Breeder

➔ *RF and US also support the TBM Program by providing R&D results*

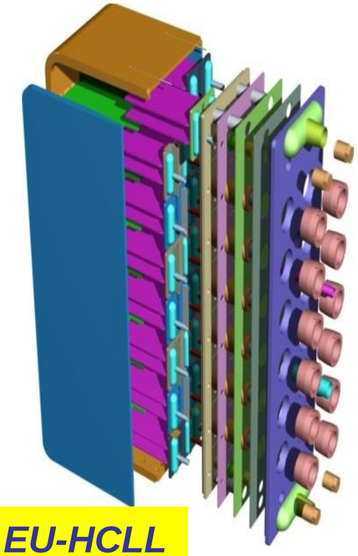
All six DEMO BB use Reduced-Activation Ferritic/Martensitic steels ➔ TBMs can correctly represent DEMO-BBs only if they use the same structural material

To note that these type of steels:

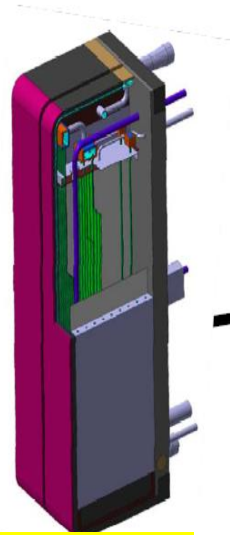
i. ☺ *Are developed to avoid rad-waste with lifetime longer than 100 years*
➔ *important for future of D-T fusion power !!!*

ii. ☹ *Are ferromagnetic* ➔ *they perturb the magnetic field in the ITER plasma. To better understand this issue, experiments in DIII-D have been performed in 2009, 2011 and 2014 (obtained promising results).*

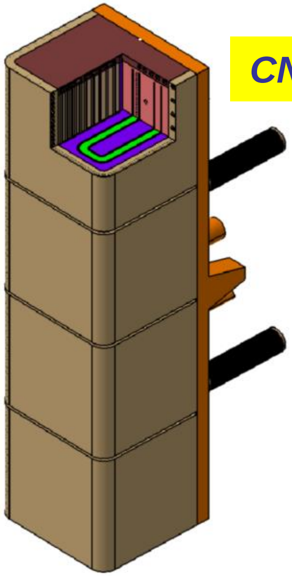
View of the 6 Test Blanket Module Designs



EU-HCLL

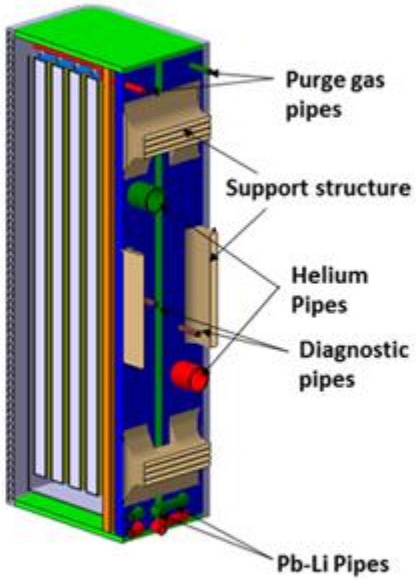


JA-WCCB

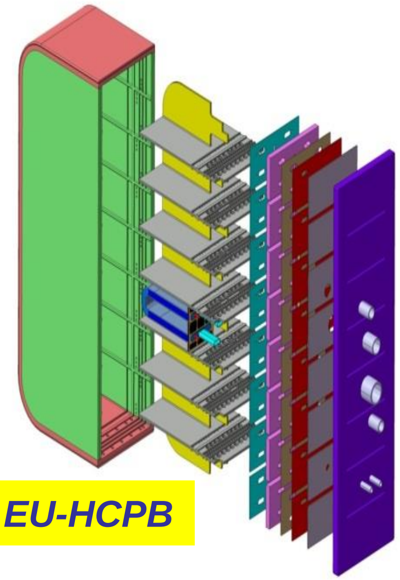


CN-HCCB

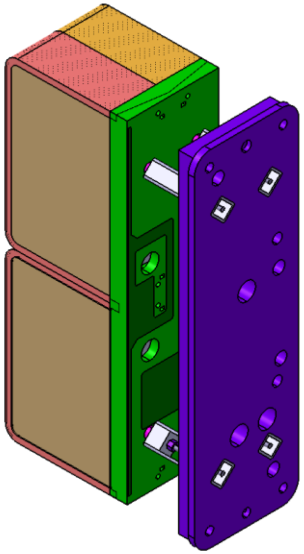
IN-LLCB



Six Test Blanket Systems



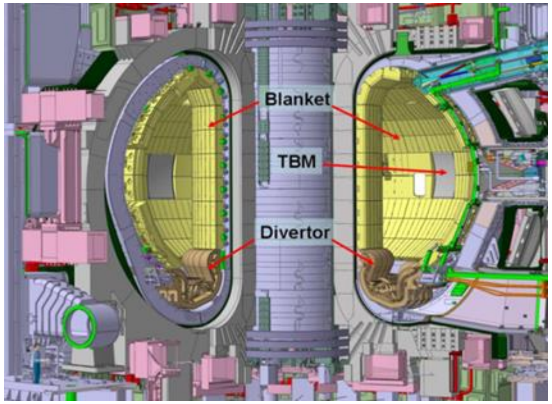
EU-HCPB



KO-HCCR

Main Characteristics of the 6 Test Blanket Modules

PP 16	**A1 – HCLL-TBM** ▪ Eurofer Steel *(structure)*, Pb-16Li *(multiplier/breeder/T-carrier)* ▪ *Coolant:* Helium at 8 MPa, 300/500°C ▪ *T-removal:* He+0.1% H_2 (0.4 MPa)	**A2 – HCPB-TBM** ▪ Eurofer Steel *(structure)*, Be pebbles *(multiplier)*; Li_4SiO_4 or Li_2TiO_3 pebbles *(breeder)* ▪ *Coolant:* He at 8 MPa, 300/500°C ▪ *Purge gas:* He+0.1% H_2 0.4 MPa
PP 18	**B3 – WCCB-TBM** ▪ F82H Steel *(struct.)*, Be pebbles *(mult.)*, Li_2TiO_3 pebbles *(breeder)* ▪ *Coolant:* H_2O at 15.5 MPa, 280 /325°C; ▪ *Purge gas:* He+0.1% H_2 (0.1 MPa)	**B4 – HCCR-TBM** ▪ RAFM Steel *(struct.)*, Be-pebbles *(multiplier)*, Li_2TiO_3 pebbles *(breeder)*, Graphite *(reflector)* ▪ *Coolant:* He at 8 MPa, 300/500°C ▪ *Purge gas:* He+0.1% H_2 (0.1 MPa)
PP 2	**C5 – HCCB-TBM** ▪ RAFM Steel *(struct.)*, Be pebbles *(mult.)*, Li_4SiO_4 pebbles *(breeder)* ▪ *Coolant:* Helium at 8 MPa, 300/500°C ▪ *Purge gas:* He+0.1% H_2 (0.3 MPa)	**C6 – LLCB-TBM** ▪ IN-RAFM Steel *(structure)*, Pb-16Li *(multiplier, T-carrier)*, Pb-16Li & Li_2TiO_3 pebbles *(breeders)* ▪ *Coolants:* He (8 MPa, 300/340°C) & Pb-16Li (1.2 MPa, 300/460°C); *Purge gas:* He+0.1% H_2 (0.12-0.15 MPa)



3 - TBM Program Test Plan and Objectives

Comparison ITER/DEMO Operating Conditions

Parameters (TBM relevant)	ITER H phase Design Values	ITER DT phase Design Values	DEMO Typical Values	Comparison ITER versus DEMO
Surface heat flux on First Wall (MW/m^2)	**0.17** (typical 0.08)	**0.30** (typical 0.15)	**0.5**	Lower but relevant
Neutron wall load (MW/m^2)	-	**0.78**	**2.5**	Much lower but relevant using engineering scaling
Pulse length (sec)	Up to **400**	400 /up to **3000**	**~ cont.**	In some cases need significant modeling
Duty cycle	**0.22**	**> 0.22**	-	-
Average neutron fluence on First Wall (MWa/m^2)	-	**0.1** *(first 10 y)* **up to 0.3** *(EOF)*	**7.5**	Too low, need of tests in other appropriate facilities

- ➔ Except for the long-term neutron irradiation effects, the Breeding Blanket performance and behaviour can be validated in ITER by operating the TBM Systems provided the used TBMs materials and technologies are the same as in DEMO
- ➔ The need of “Engineering scaling” requires the testing different TBM versions during the different ITER

Adopted Strategy for the TBM Program Testing Plan

- The operation of the TBS must not jeopardize ITER performance, reliability / availability and safety
  ➔the TBM testing plan has to be adapted to the ITER operation plan

- Up to 4 design versions per each TBM (with similar structures but different installed diagnostic) will be operated in order to take into account the various ITER operation conditions and to reach DEMO-relevant operational conditions

➔ ***the TBM Port Plugs have to be replaced ~4 times***

Typical TBS testing sequence:

- TBS learning/validation phase
  - the Electro Magnetic version (EM-TBM): during the initial H phase and H-He phase
  - the Thermal/Neutronic version (TN-TBM): during D & initial DT phase (low duty)
- TBS data acquisition phase
  - the Neutronic/Tritium & Thermo-Mechanical version (NT/TM-TBM): during further DT phase (regular pulses)
  - the INTegral TBM (INT-TBM): during later DT phase (high duty, long pulses)

Objectives of the TBM Program

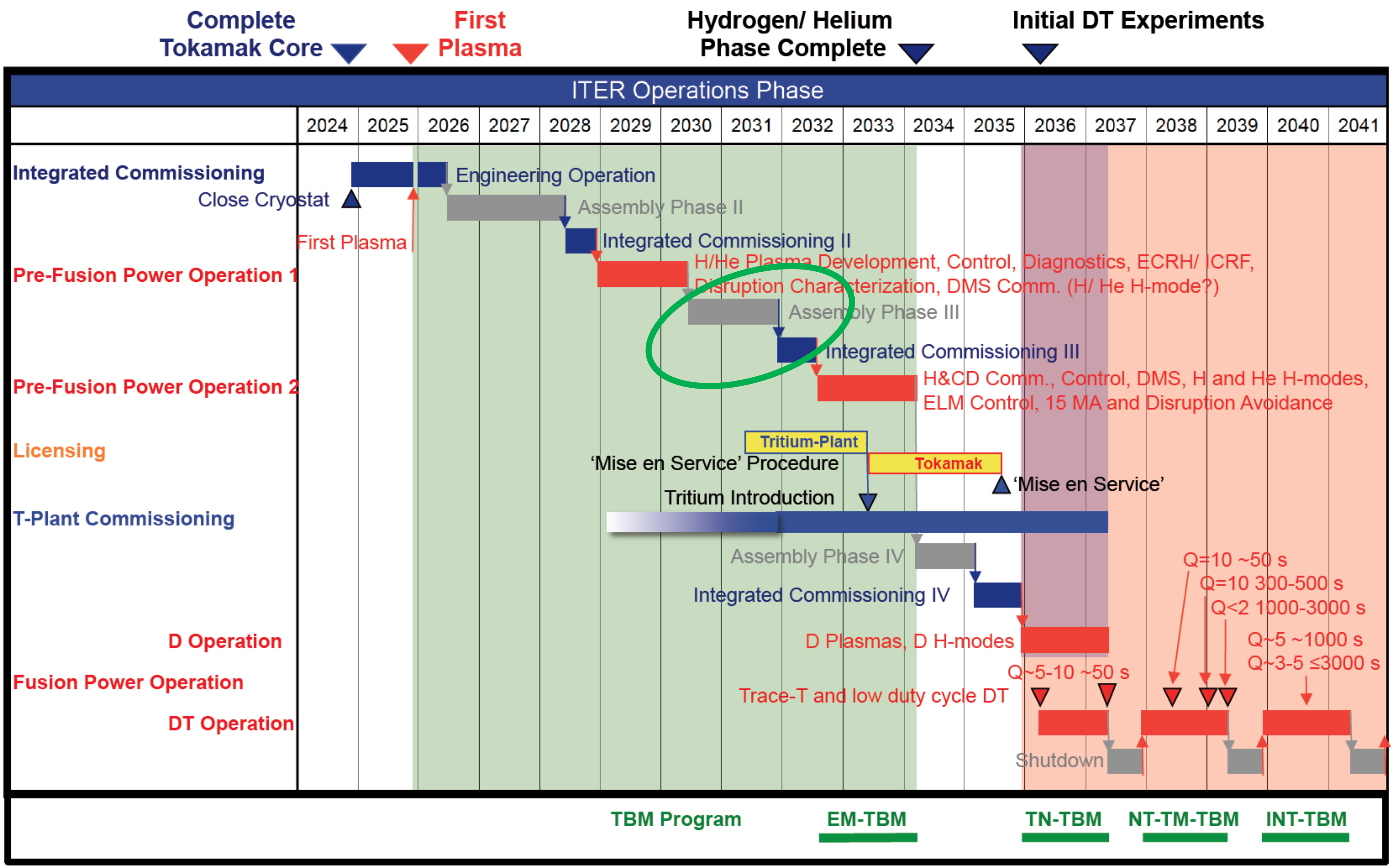
"TBS Learning/Qualification Phase" during the ITER non-nuclear phase (H, H/He)

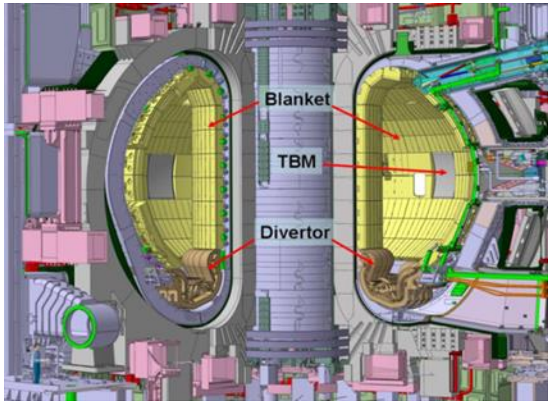
- **Verify/qualify** the Test Blanket Systems full operations in ITER operative environment
- **Demonstrate** the coolant capability of the TBMs first wall and TBM resistance to ITER disruptions
- **Acquire essential data** to be used for the nuclear licensing process
- **Verify/confirm** that the TBMs do not jeopardize the quality of plasma confinement during H-mode operation and, from the D-phase, start measurements on TBM neutronics responses

"TBS Data acquisition phase" during the ITER nuclear phase (D, D-T)

- **Validation** of the nuclear response prediction with existing modelling codes and nuclear data
- **Assessment** of the TBMs thermo-mechanical behaviour at relevant temp. and volume heat sources
- **Demonstration** of the tritium management, including validation of Tritium extraction techniques and permeation reduction capability
- Breeding Blanket **performance** for an extended period of time in order to obtain initial reliability data
- Post-Irradiation Examinations (PIEs) for material/process data

ITER Research Plan and associated TBM Program

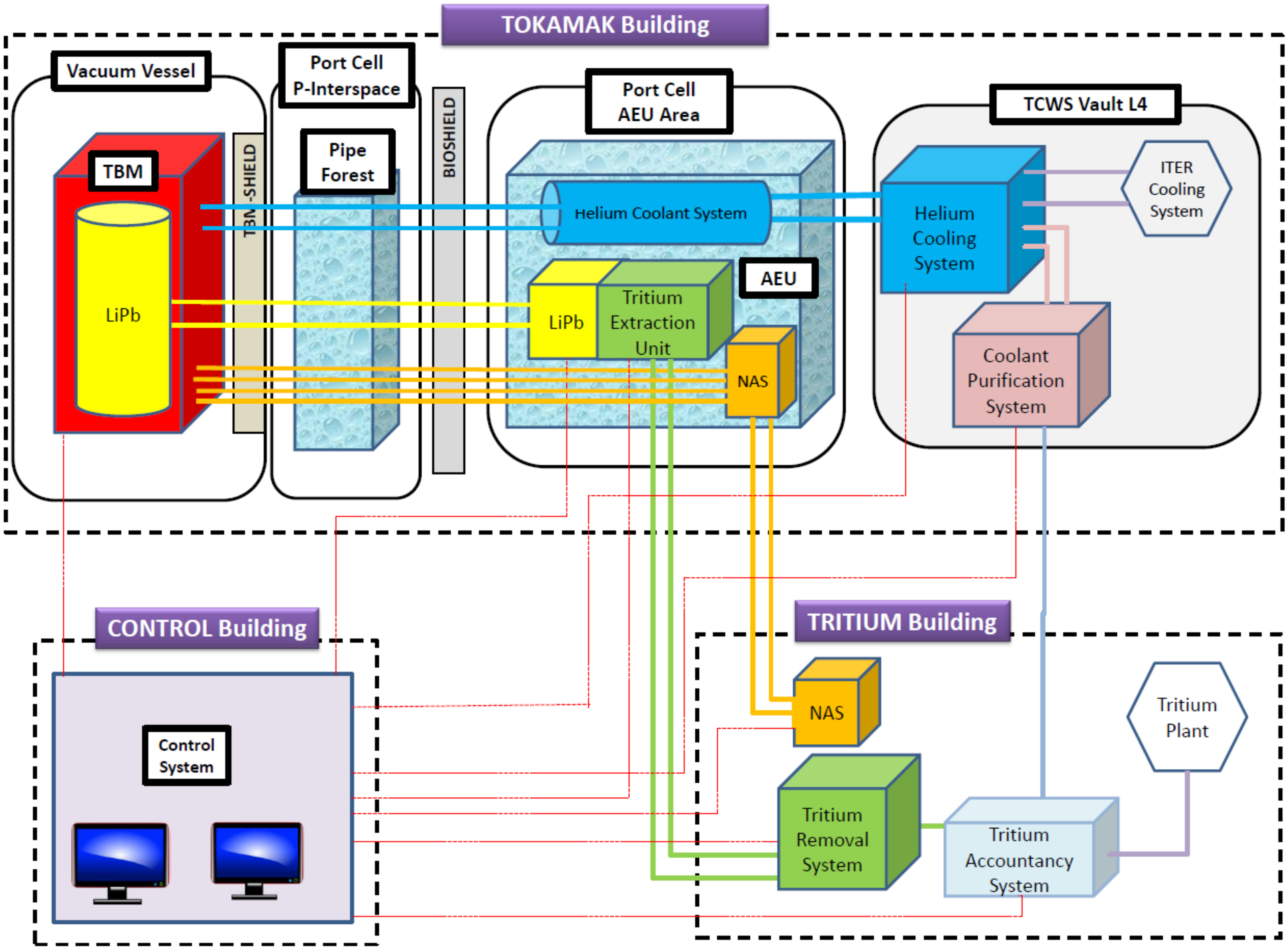




4 – Test Blanket Systems Integration in the ITER Tokamak Complex Buildings and Port Cell Maintenance

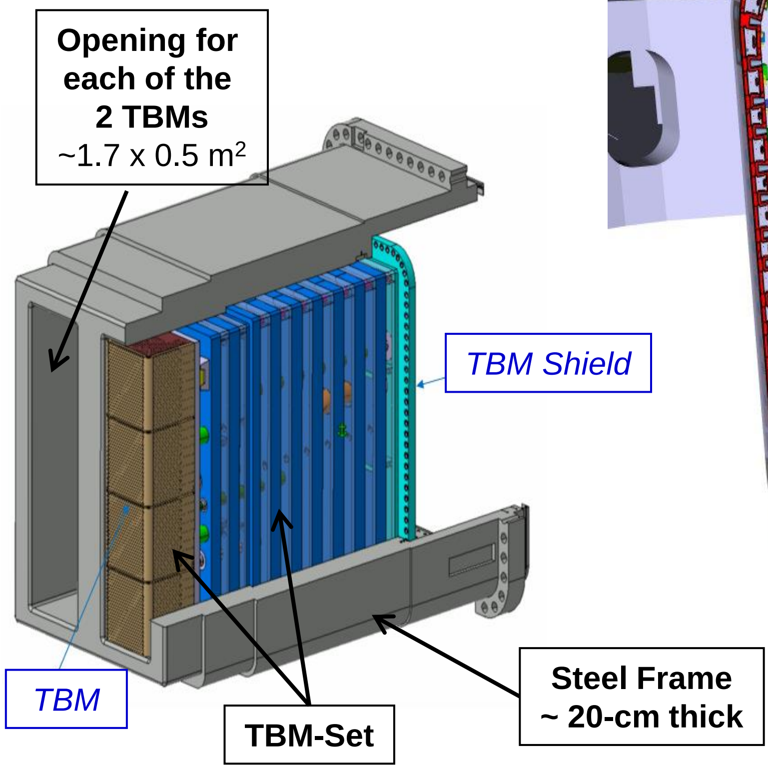
Scheme of a Test Blanket System

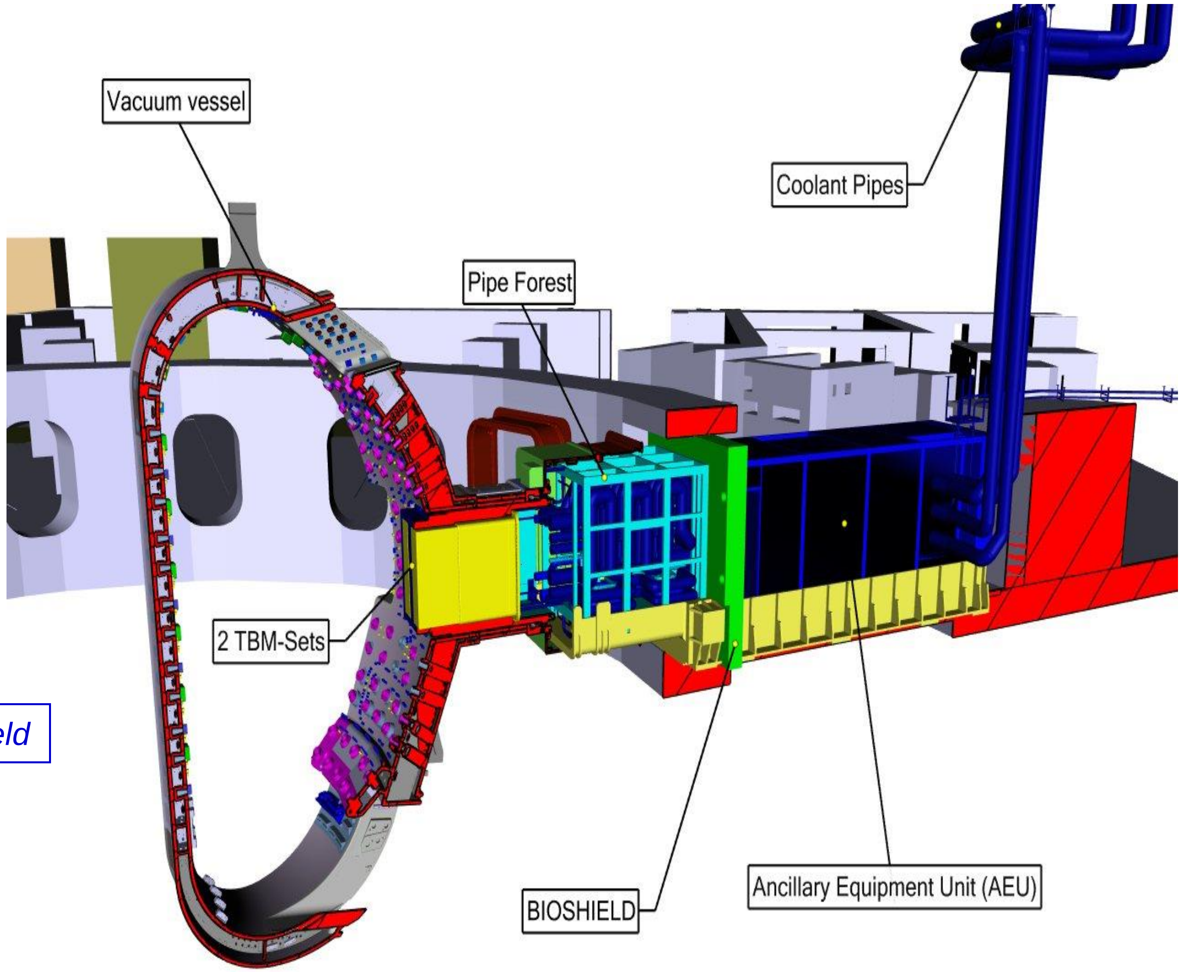
Example of the HCLL TBS - Locations in the various ITER buildings



View of a TBM Port Plug and a TBM Port Cell

View of
- Equatorial TBM Port Plug
- Port Interspace
- Bio-shield Plug
- Port Cell Area
  behind Bio-shield

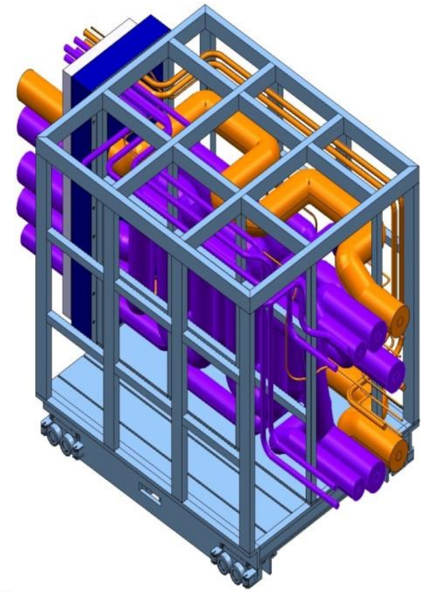


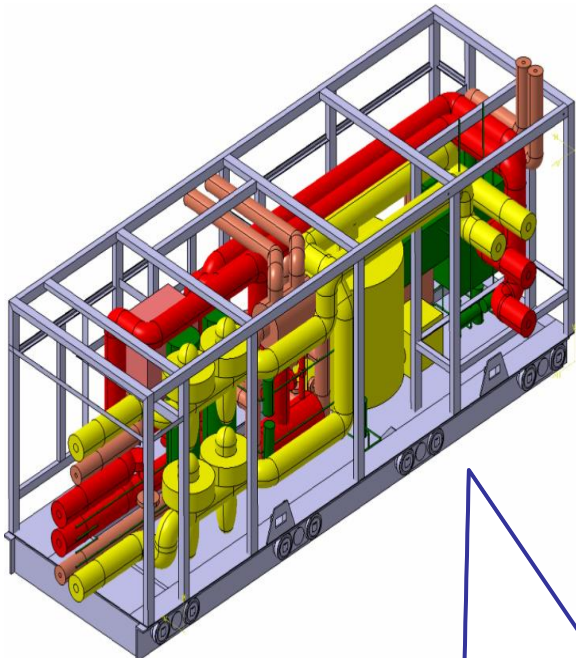


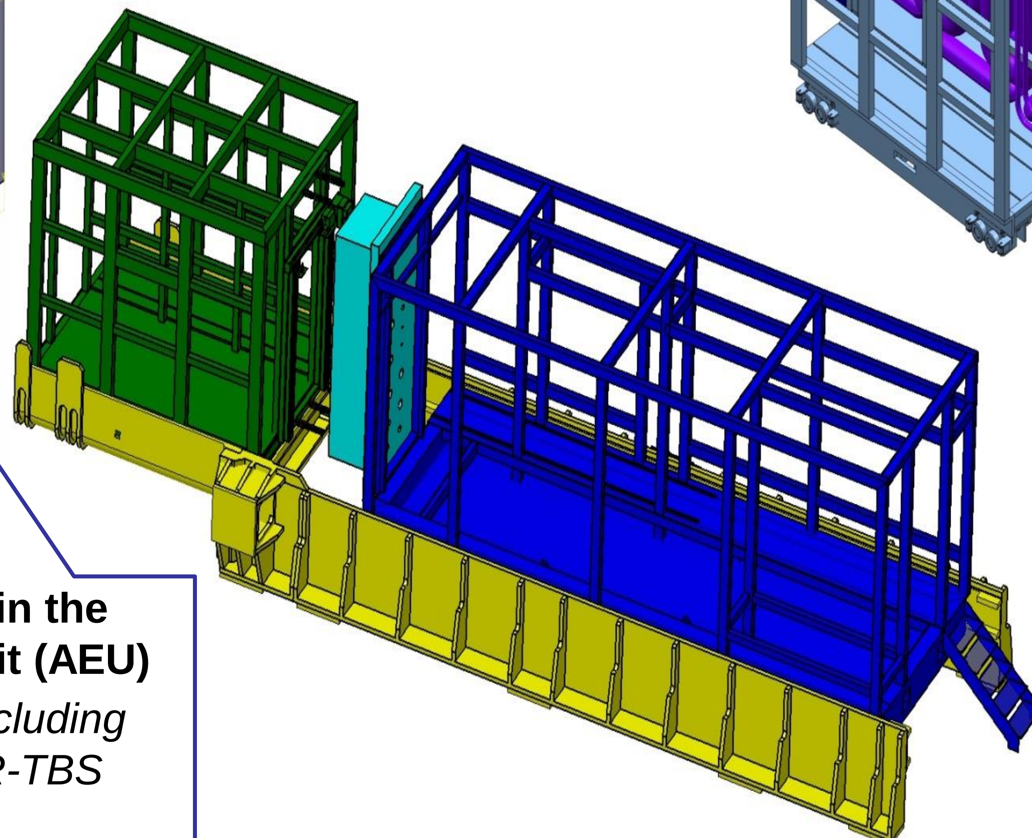
Conceptual Design of the main Port Cell Components (1/2)

Pipe Forest including pipes

(example of PF#18)





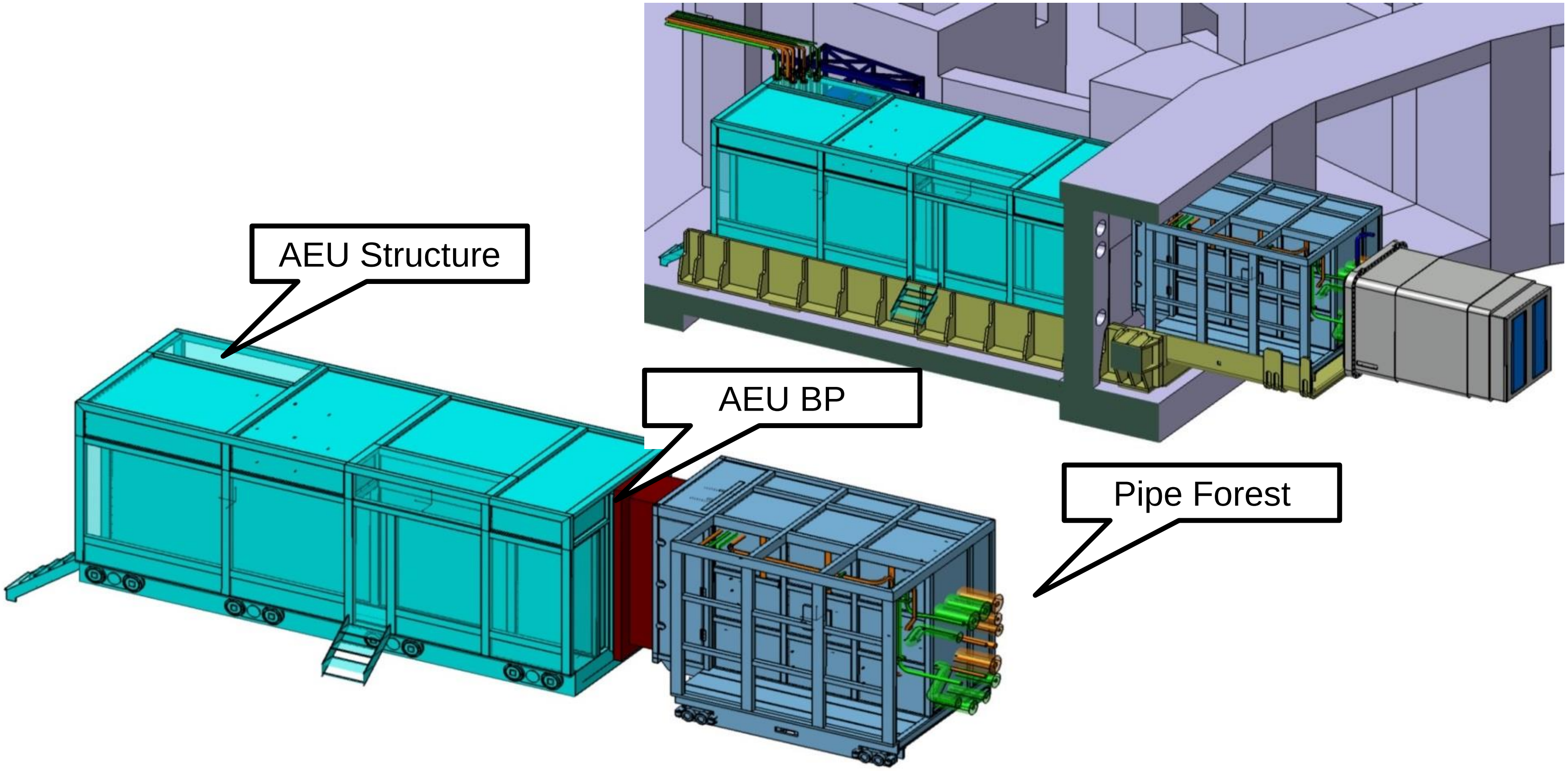


Internal Components in the Ancillary Equipment Unit (AEU)

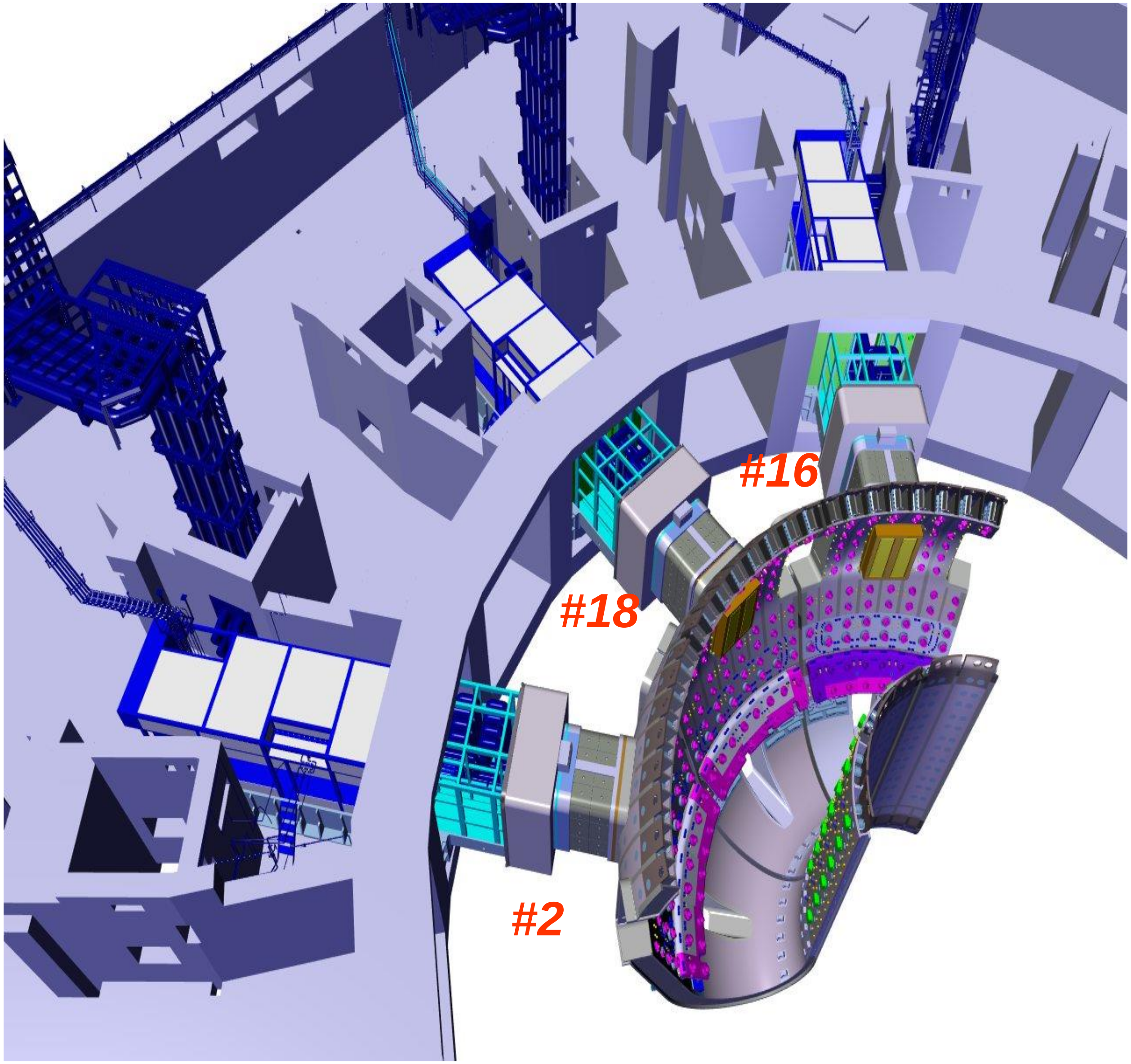
(example of Port #18, including WCCB-TBS and HCCR-TBS components)

Conceptual Design of the main Port Cell Components (2/2)

Enclosure of Pipe Forest and AEU to manage Tritium contamination in the TBM Port Cells: 3D CATIA model



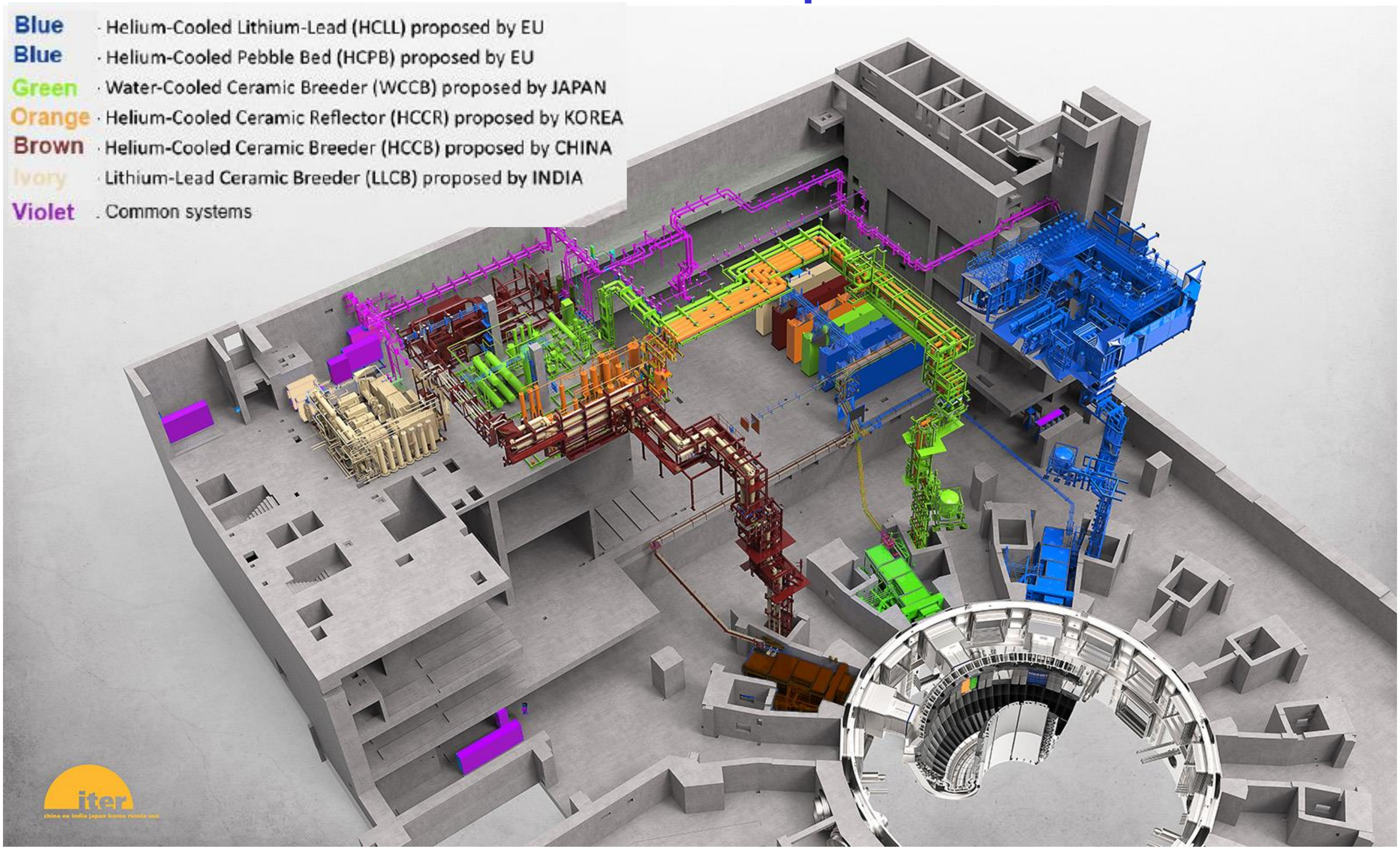
View of the 3 TBM Port Cells *(#02, #18 and #16)*



Main Components in each TBM Port Cell (common to 2 TBSs):

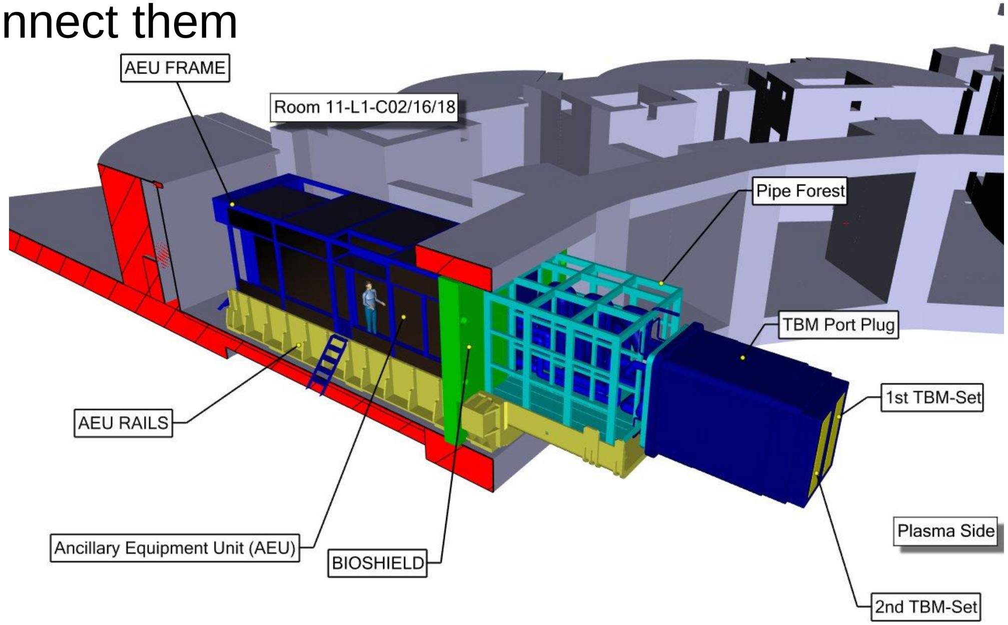
- *Pipe Forest (essentially pipes)*
- *Bio-shield Plug*
- *Ancillary Equipment Unit (AEU) including:*
  - ✓ *Few Cooling Systems Components*
  - ✓ *Part of the Tritium Extraction Systems*
  - ✓ *The whole LiPb System (#2 and #16)*

Overall View of the 6 Test Blanket Systems in the Tokamak Complex



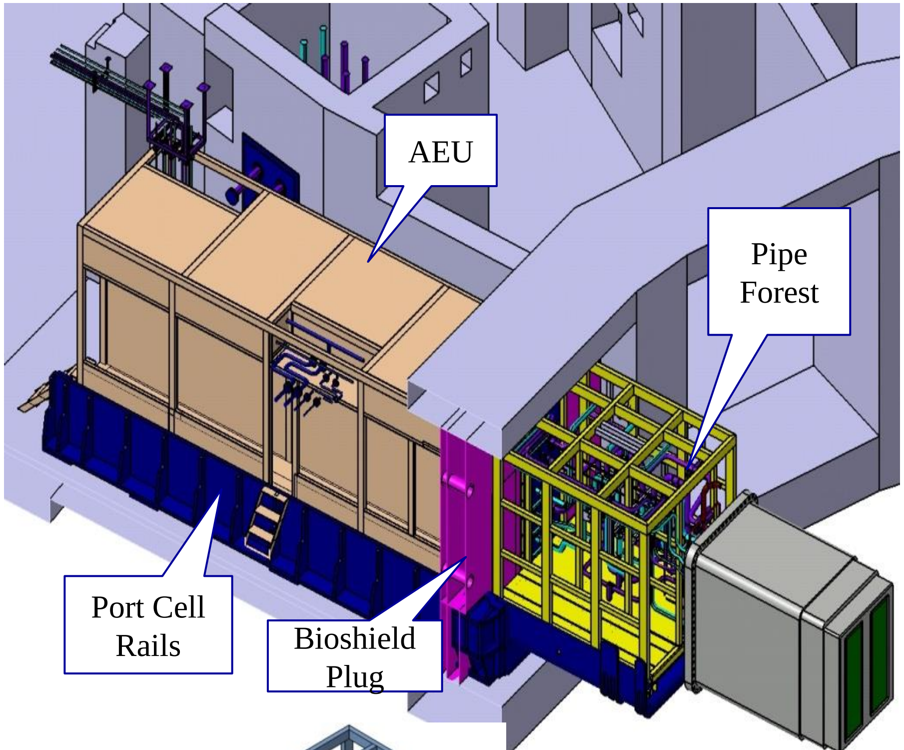
Main required Maintenance Operations in the Port Cells to replace the TBM Port Plugs

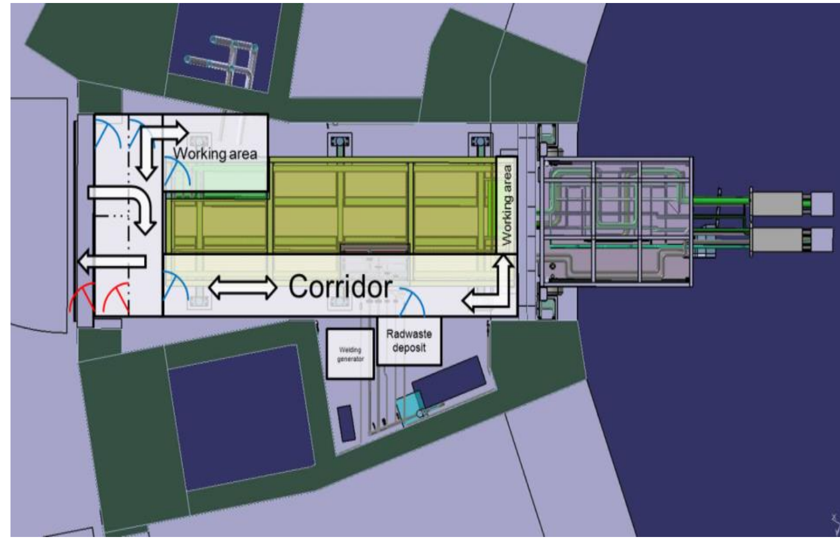
- Disconnect AEU and transfer it in the Hot Cell facility (on-line maintenance)
- Disconnect Pipe Forest and transfer it in the Hot Cell facility (waste)
- Arrival of the Transfer Cask, disconnect the TBM Port Plug, charging the TBM Port Plug on the TC and transfer in the Hot Cell Facility for TBM-sets refurbishment (off-line maintenance)
- Charge a new TBM Port Plug, transfer it in the Port Cell and install it in the VV
- Transfer the maintained AEU & Pipe Forest from the HCF to the Port Cell and reconnect them

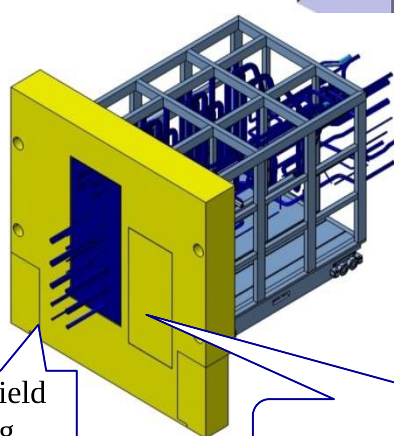


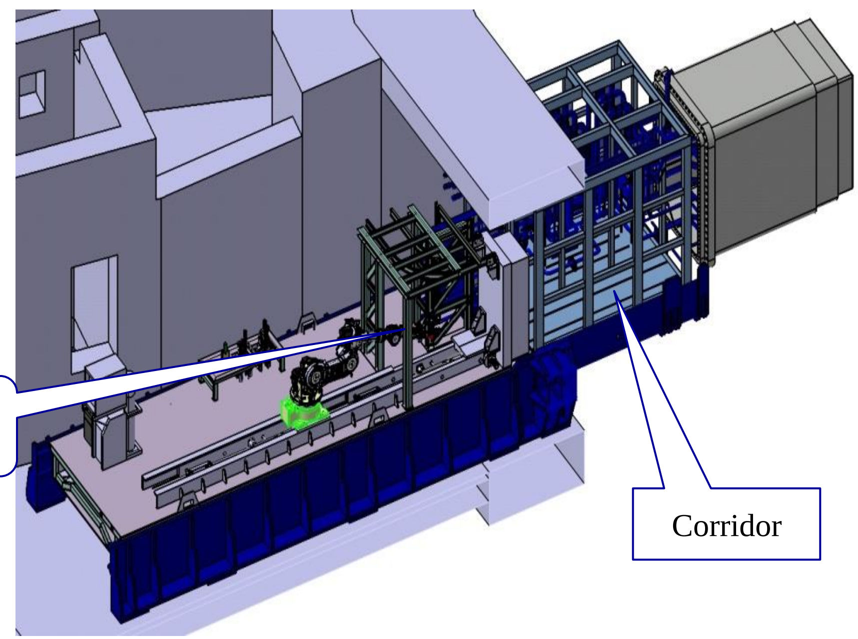
A large use of Hot Cell Facility is required

Replacement of TBM Port Cell Components



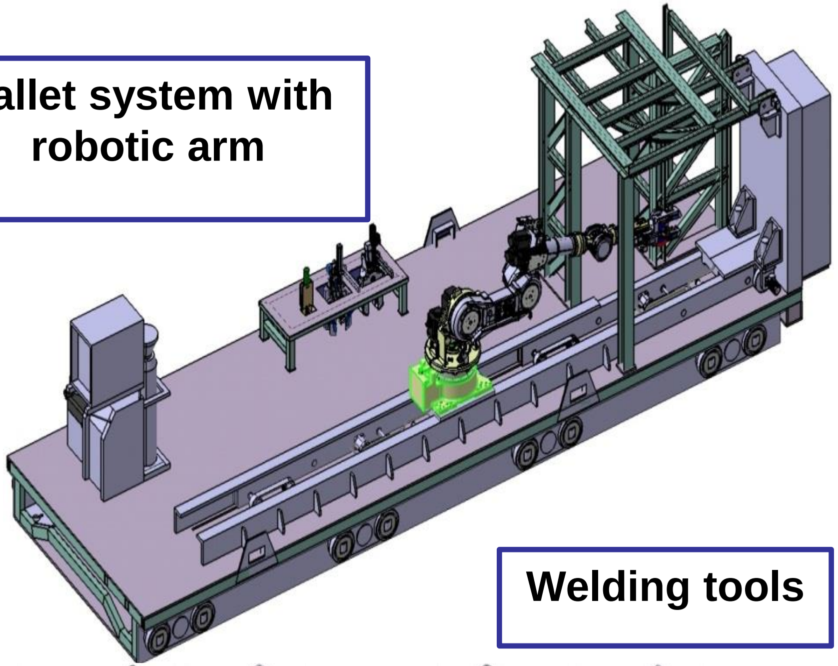




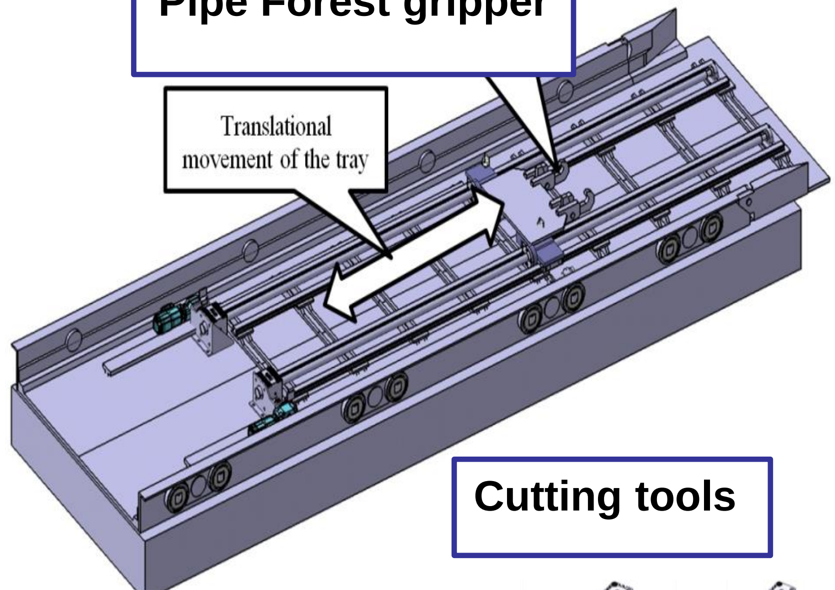


Possible Port Cell Maintenance Tools (IO Procurement)

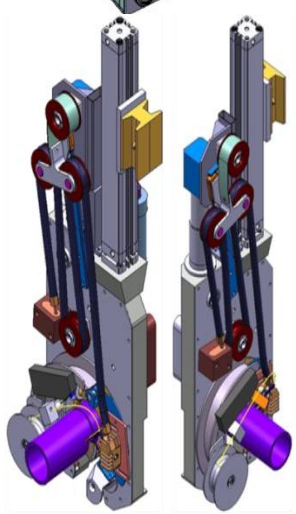
Pallet system with robotic arm



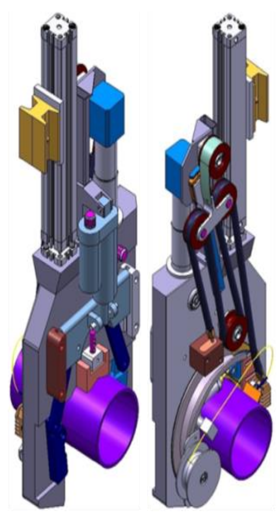
Pallet system with Pipe Forest gripper



Welding tools

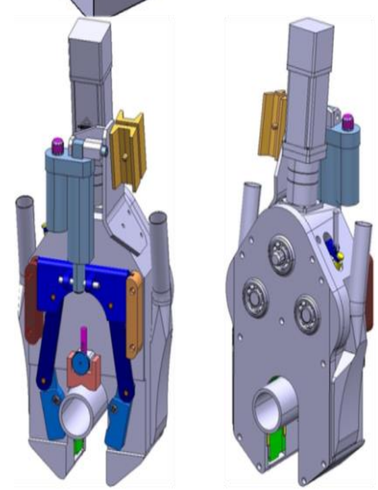


Orbital TIG welding for pipes DN15 to DN50

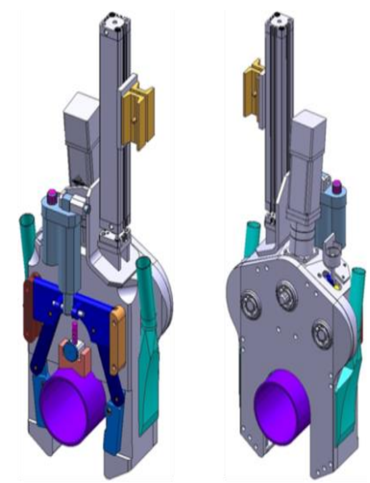


Orbital TIG welding for pipes DN50 to DN100

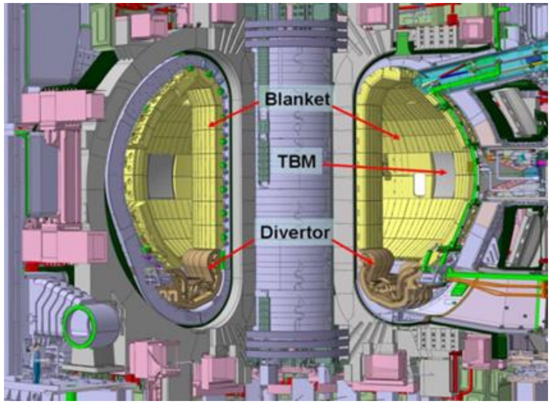
Cutting tools



Cutting tool for pipes DN15 to DN50



Cutting tool for pipes DN50 to DN100



5 – Main Sub-systems of the Test Blanket System

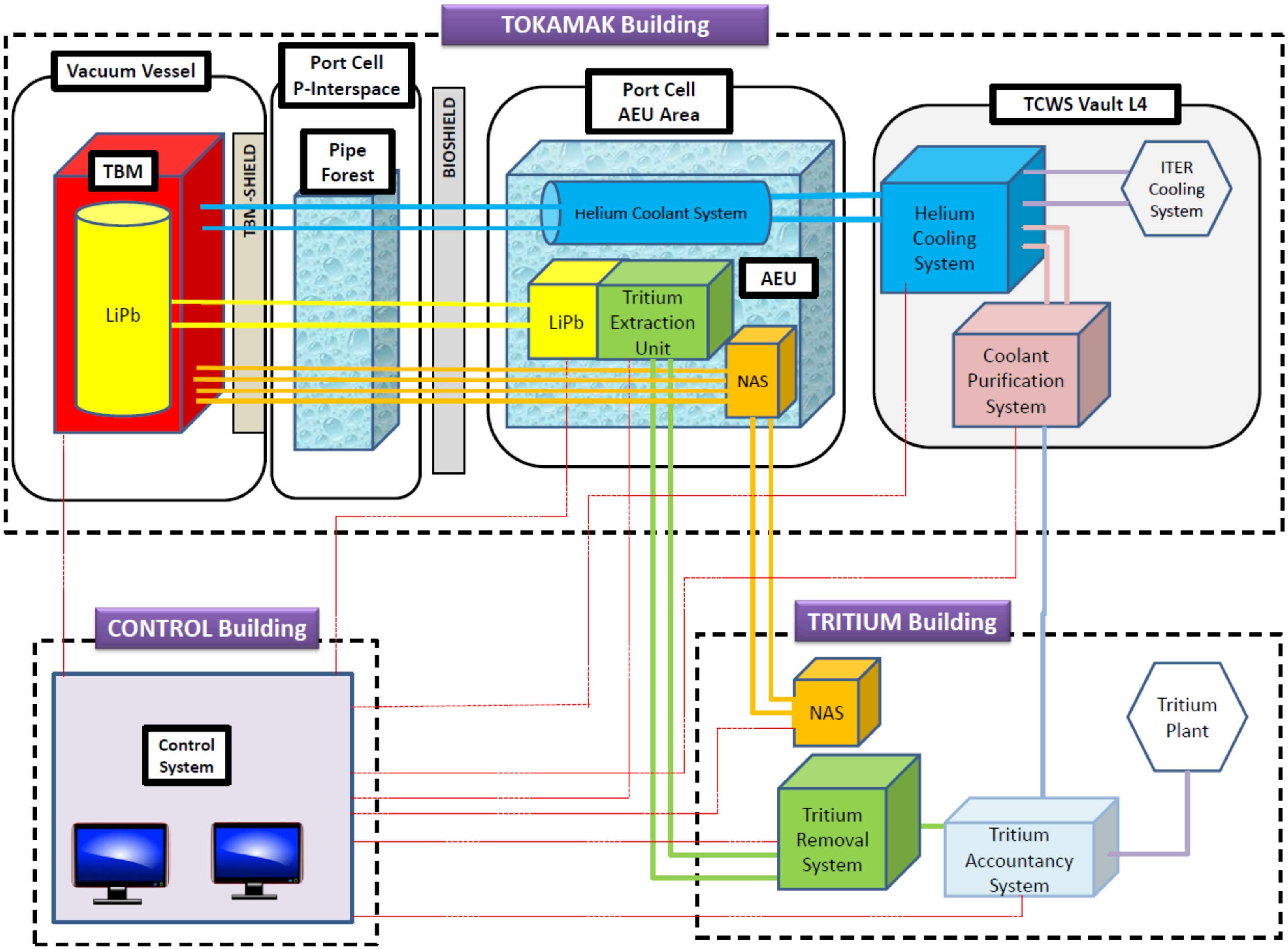
Main sub-systems for each TBSs

P P 16	**A1 – HCLL-TBS** ▪ *Helium Coolant System + CPS (Tritium)* ▪ *Lithium-Lead System (Tritium carrier)* ▪ *Tritium Extraction System (from LiPb)* ▪ *Tritium Accountancy System* ▪ *Neutron Activation System* ▪ *Instrumentation & Control Systems*	**A2 – HCPB-TBS** ▪ *Helium Coolant System + CPS (Tritium)* ▪ *Tritium Extraction System (He purge gas)* ▪ *Tritium Accountancy System* ▪ *Neutron Activation System* ▪ *Instrumentation & Control Systems*
P P 18	**B3 – WCCB-TBS** ▪ *Water Coolant System* ▪ *Tritium Extraction System (He purge gas)* ▪ *Tritium Accountancy System* ▪ *Neutron Activation System* ▪ *Instrumentation & Control Systems*	**B4 – HCCR-TBS** ▪ *Helium Coolant System + CPS (Tritium)* ▪ *Tritium Extraction System (He purge gas)* ▪ *Tritium Accountancy System* ▪ *Neutron Activation System* ▪ *Instrumentation & Control Systems*
P P 2	**C5 – HCCB-TBS** ▪ *Helium Coolant System + CPS (Tritium)* ▪ *Tritium Extraction System (He purge gas)* ▪ *Tritium Accountancy System* ▪ *Neutron Activation System* ▪ *Instrumentation & Control Systems*	**C6 – LLCB-TBS** ▪ *Helium Coolant System + CPS (Tritium)* ▪ *Lithium-Lead System (Tritium carrier & coolant) + secondary He-coolant* ▪ *Tritium Extraction System (He purge gas)* ▪ *Tritium Accountancy System* ▪ *Neutron Activation System* ▪ *Instrumentation & Control Systems*

Note: Detailed Process Flow (PFD) and Piping & Instrumentation (P&ID) diagrams are available (at CD level) but are not readable in a presentation slides. Therefore, only one example will be shown and CATIA models

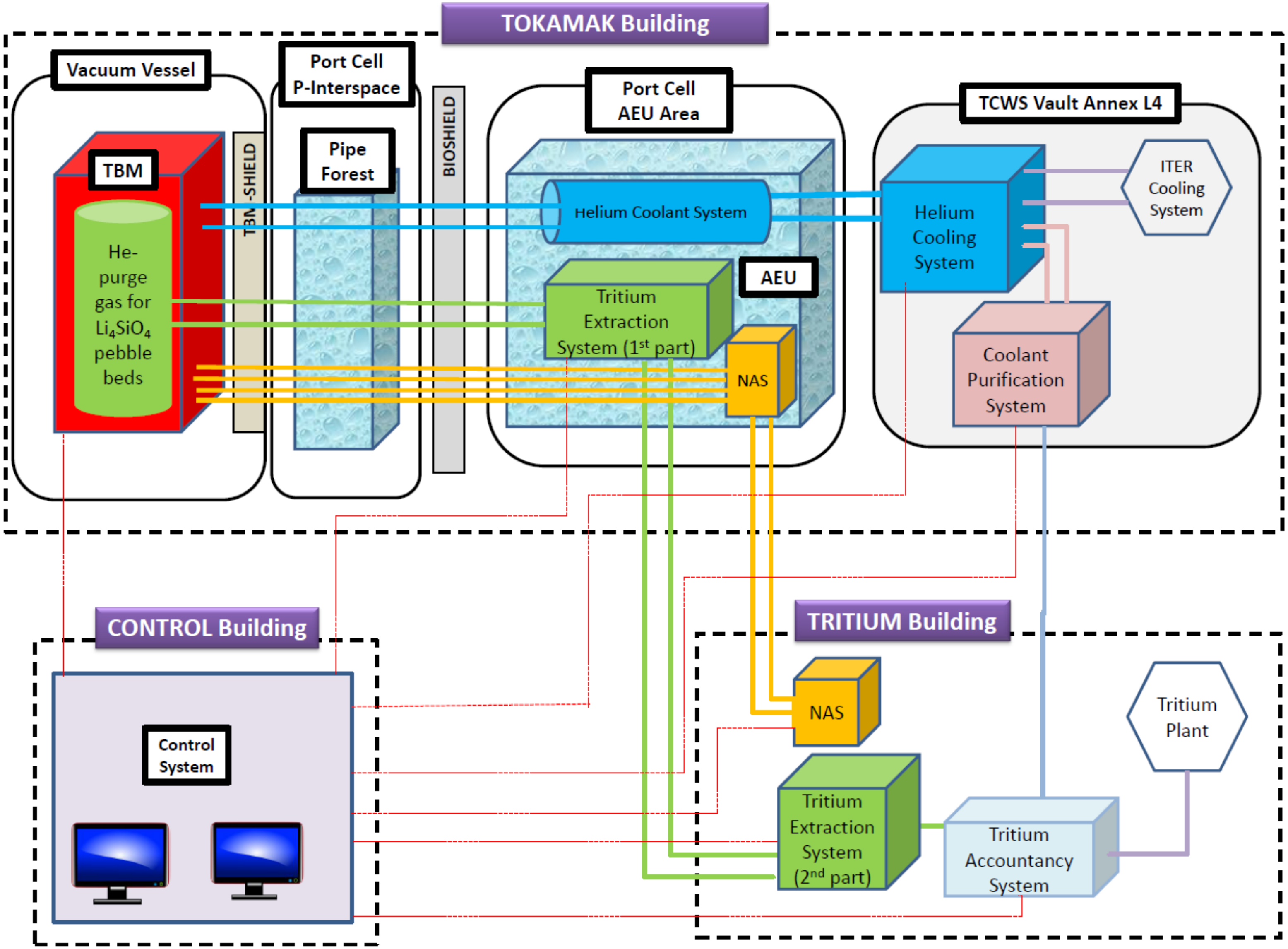
Scheme of a Test Blanket System (Liquid Breeder)

Example of the HCLL TBS - Locations in the various ITER buildings



Scheme of a Test Blanket System (Solid Breeder)

Example of the HCCB TBS - Locations in the various ITER buildings



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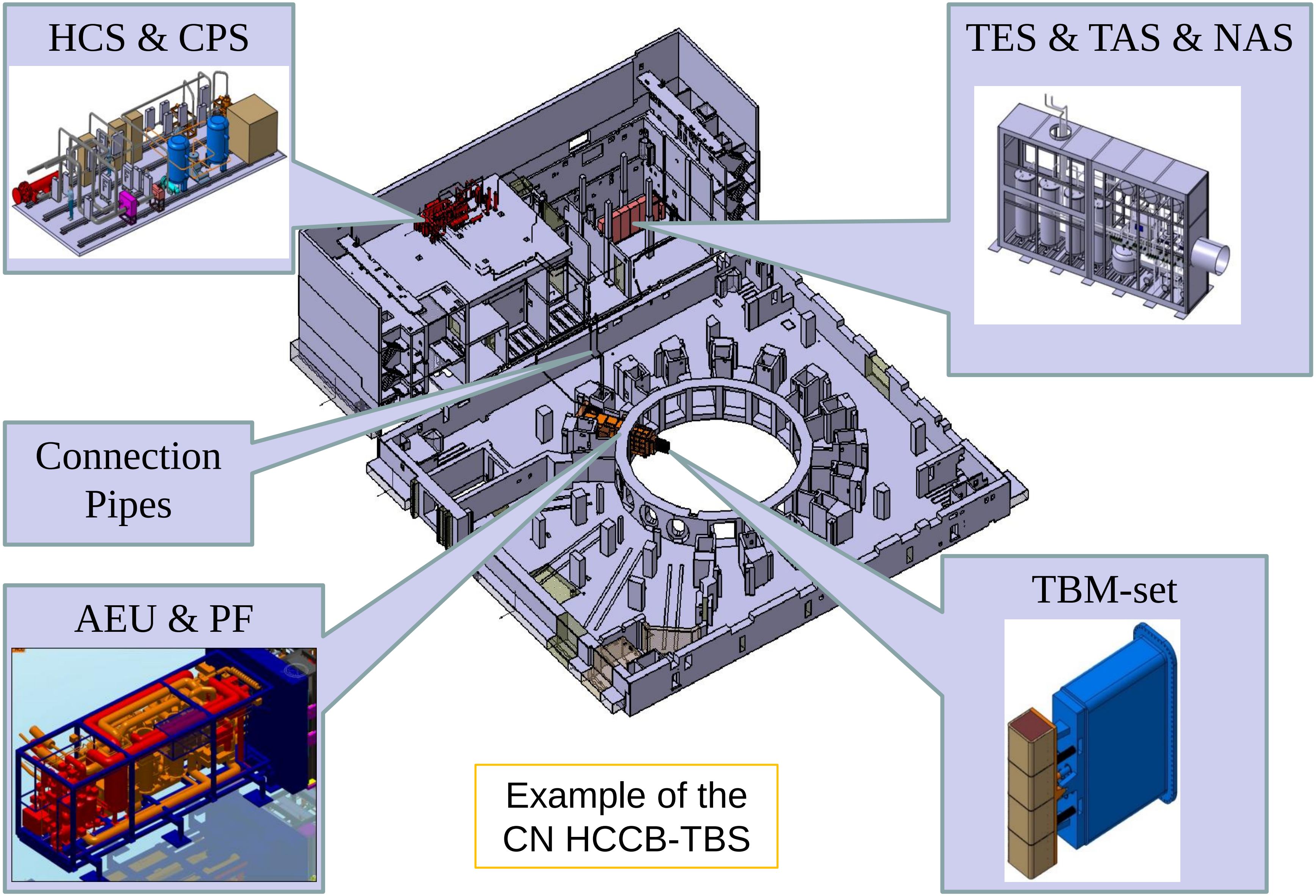
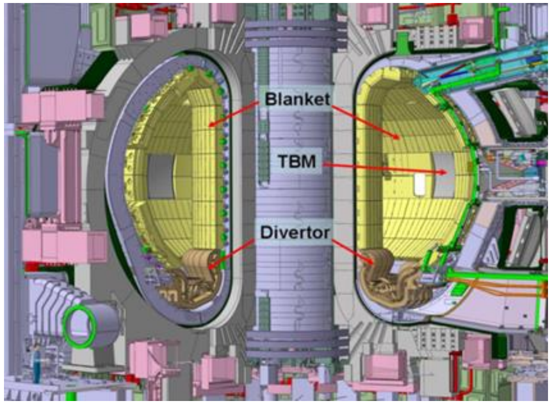
Location of the main CN Test Blanket System Components





5 a – Main Features of Helium Coolant Systems & He-Coolant Purification Systems (Tritium)

(Applicable to HCLL, HCPB, HCCR, HCCB, LLCB TBSs)

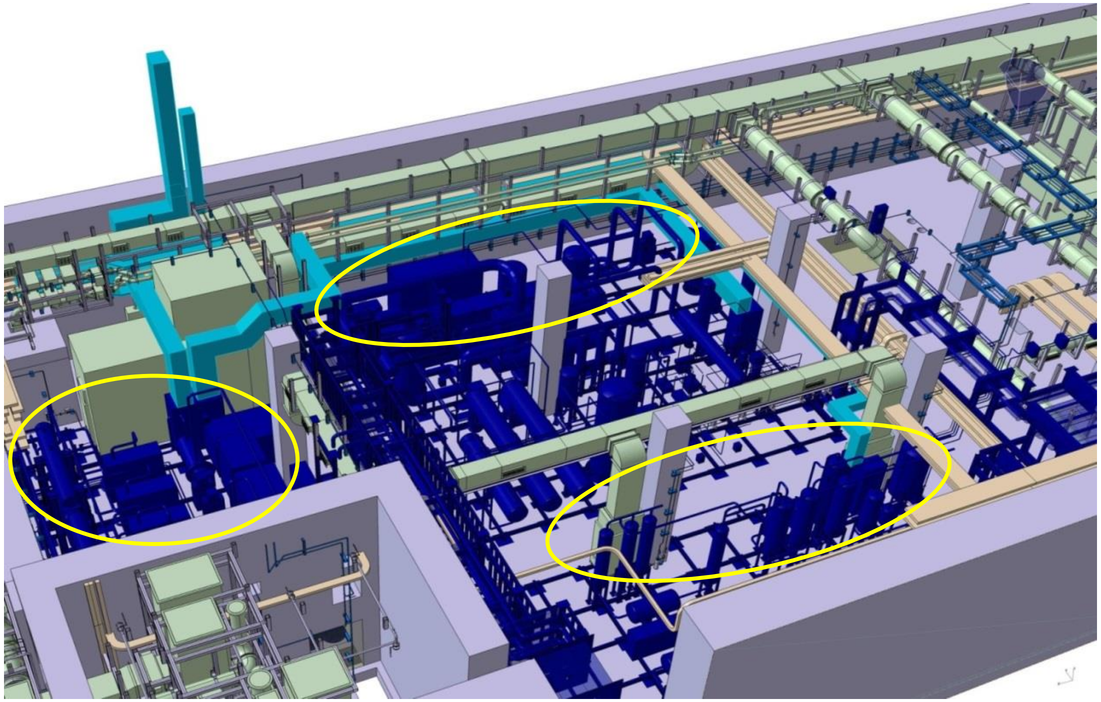
Main Characteristics of a typical HCS (+CPS)

For each He-coolant system + CPS:
Footprint : ~80 m^2
Height ~7 m

Main characteristics of the Helium Coolant Systems:

- Inlet/Outlet Temperature: 300/500 °C
- Operating Pressure: 8 MPa
- Flow-rate: 1.3 kg/s
- Total He inventory: ~40kg
- Temperature of the secondary water coolant: inlet/outlet 31/42 °C

Need of an electrical heater of ~400 kW at 400 Vac to increase the He-temperature at inlet value.

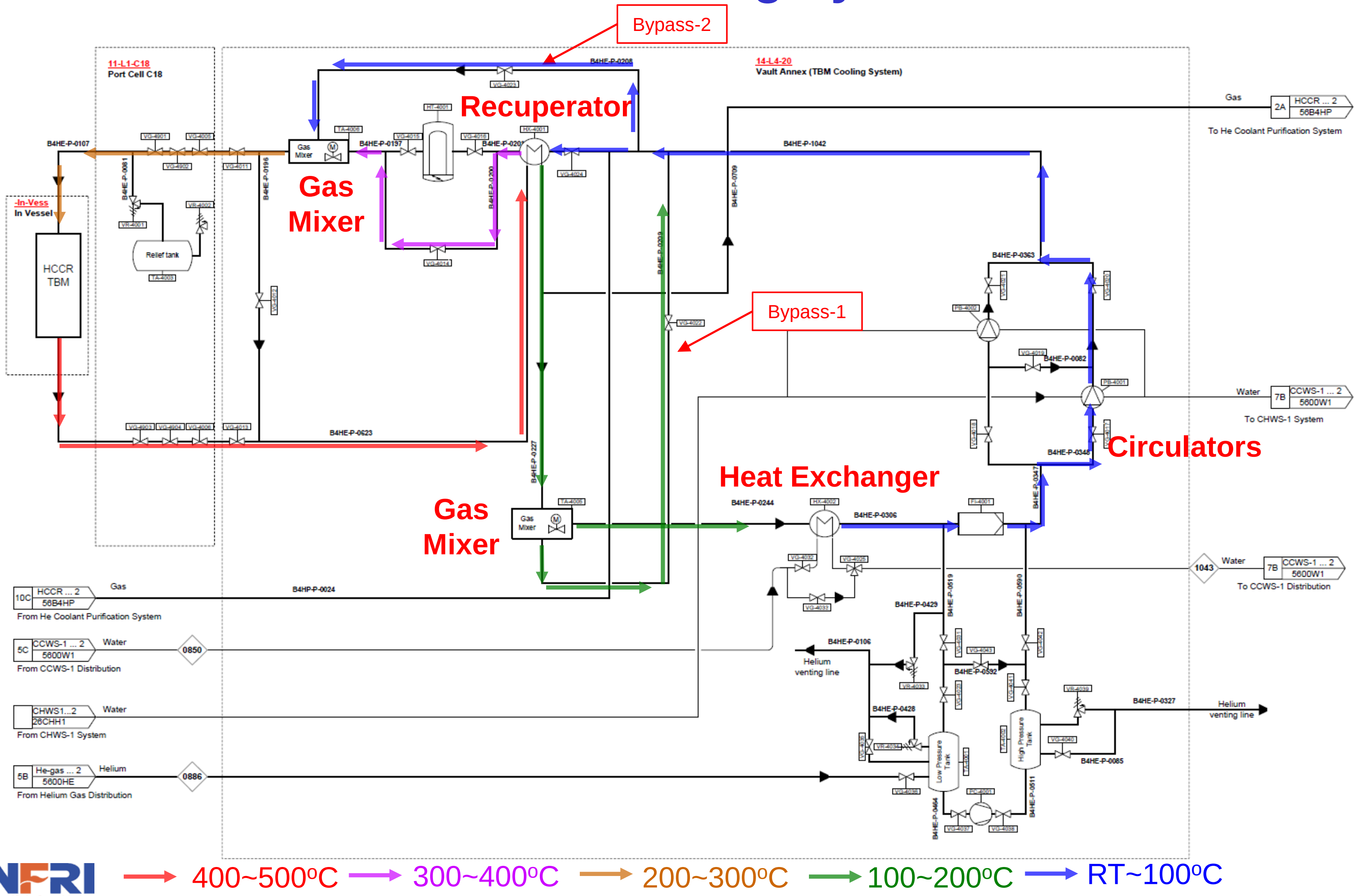


Typically, need of two circulators per system in order to improve reliability (redundancy).

- Cooled by chilled water (inlet ~6 °C), operating with He at low temperature (<100 °C)
- Power supply: ~300 kW at 400 Vac (potential need of adding a transformer since the power is supplied is at 6.6 kV).

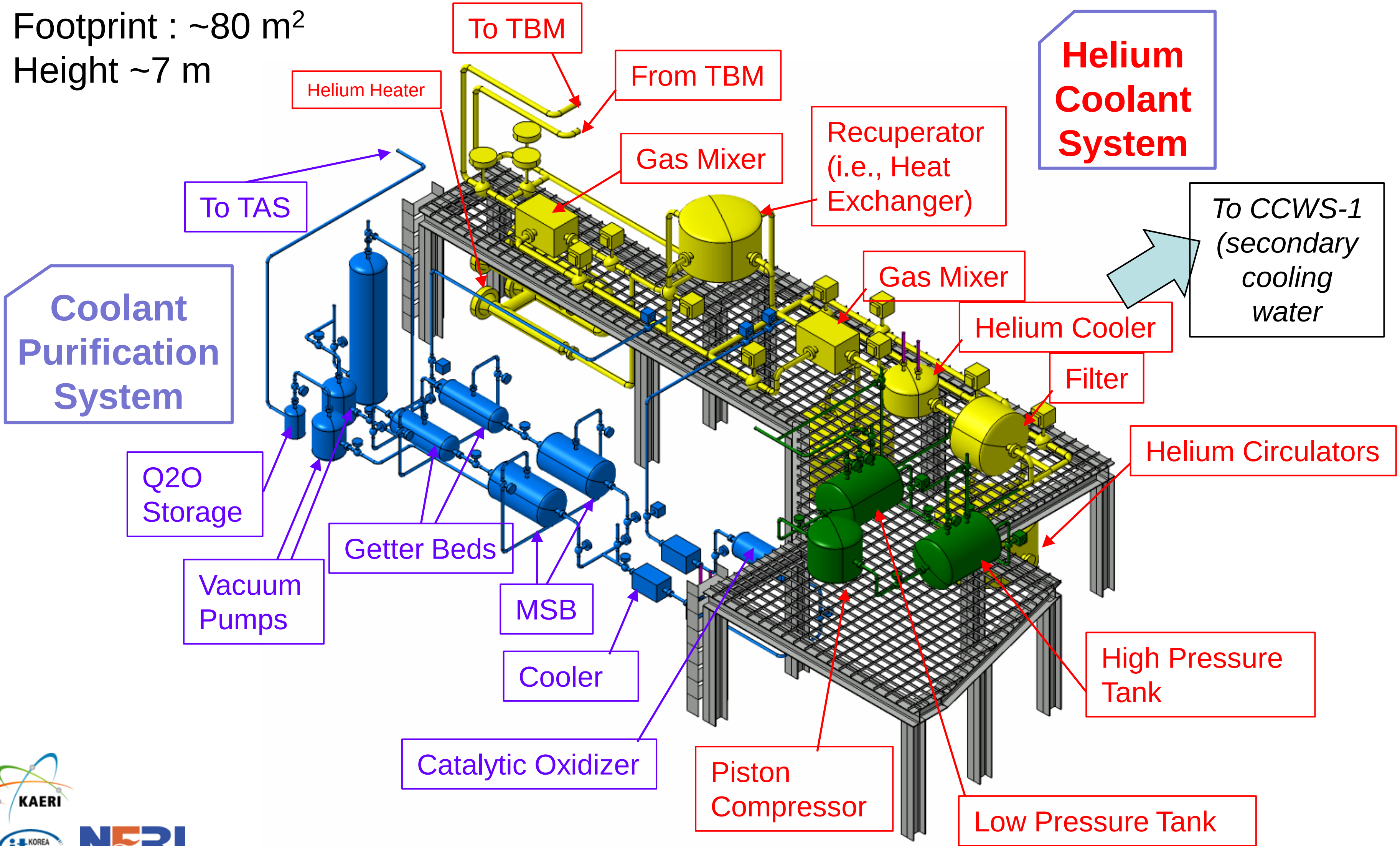
Example of Process Flow Diagrams

The KO HCCR He-Cooling System PFD

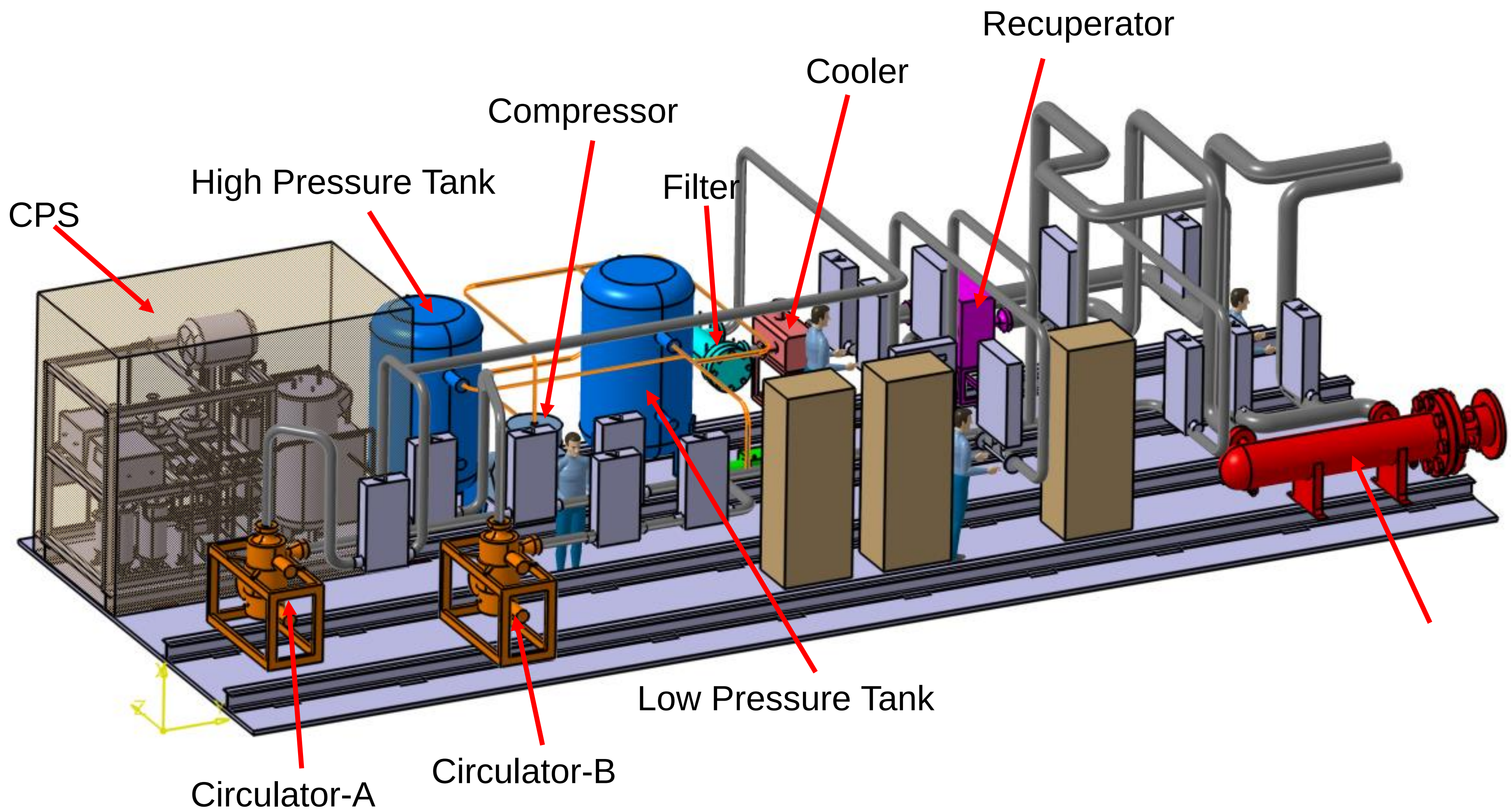


Main Components of the KO HCCR He-Cooling System + Coolant Purification System (Tritium)

Footprint : ~80 m^2
Height ~7 m

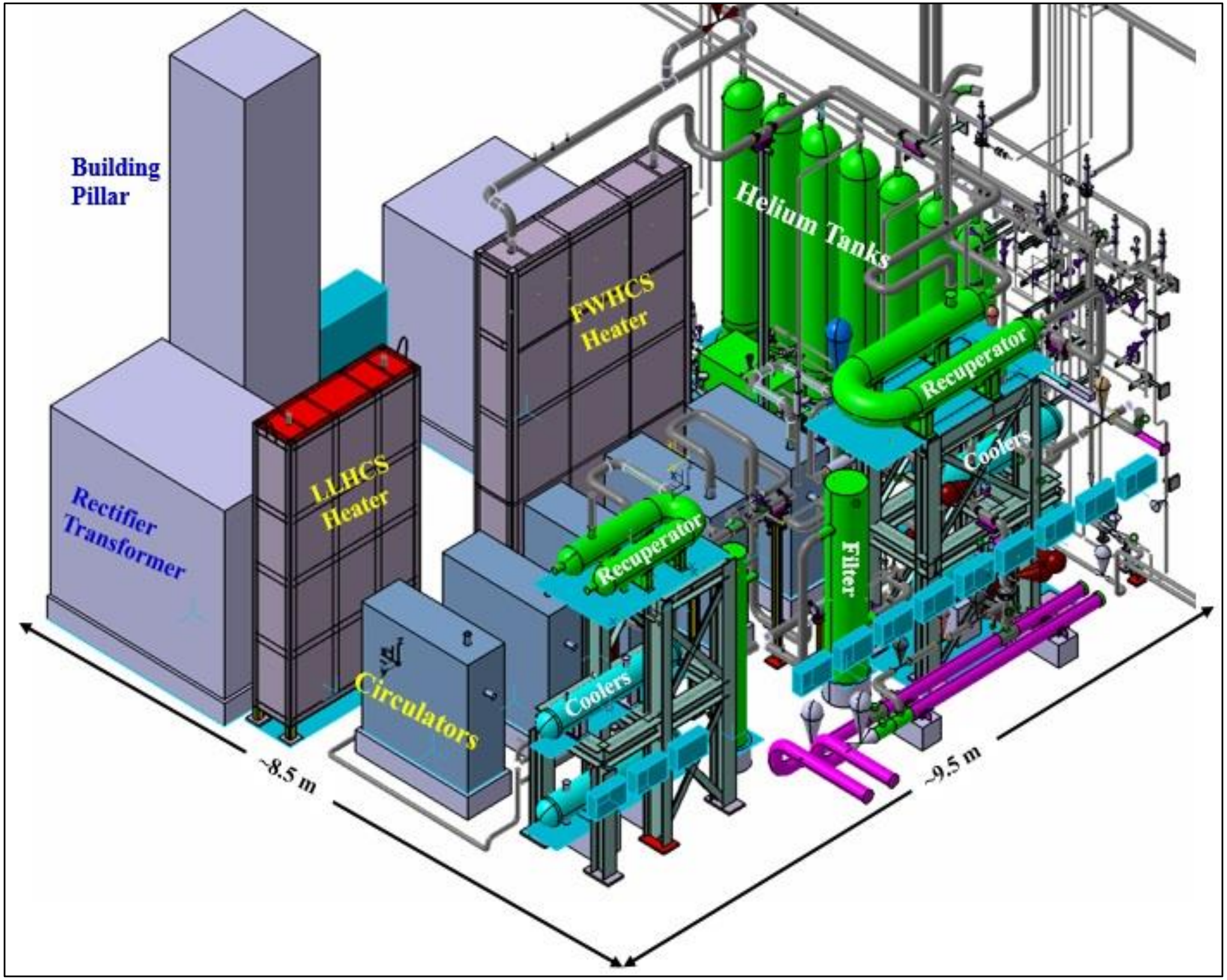


CATIA model of the CN HCCB-HCS (+CPS)



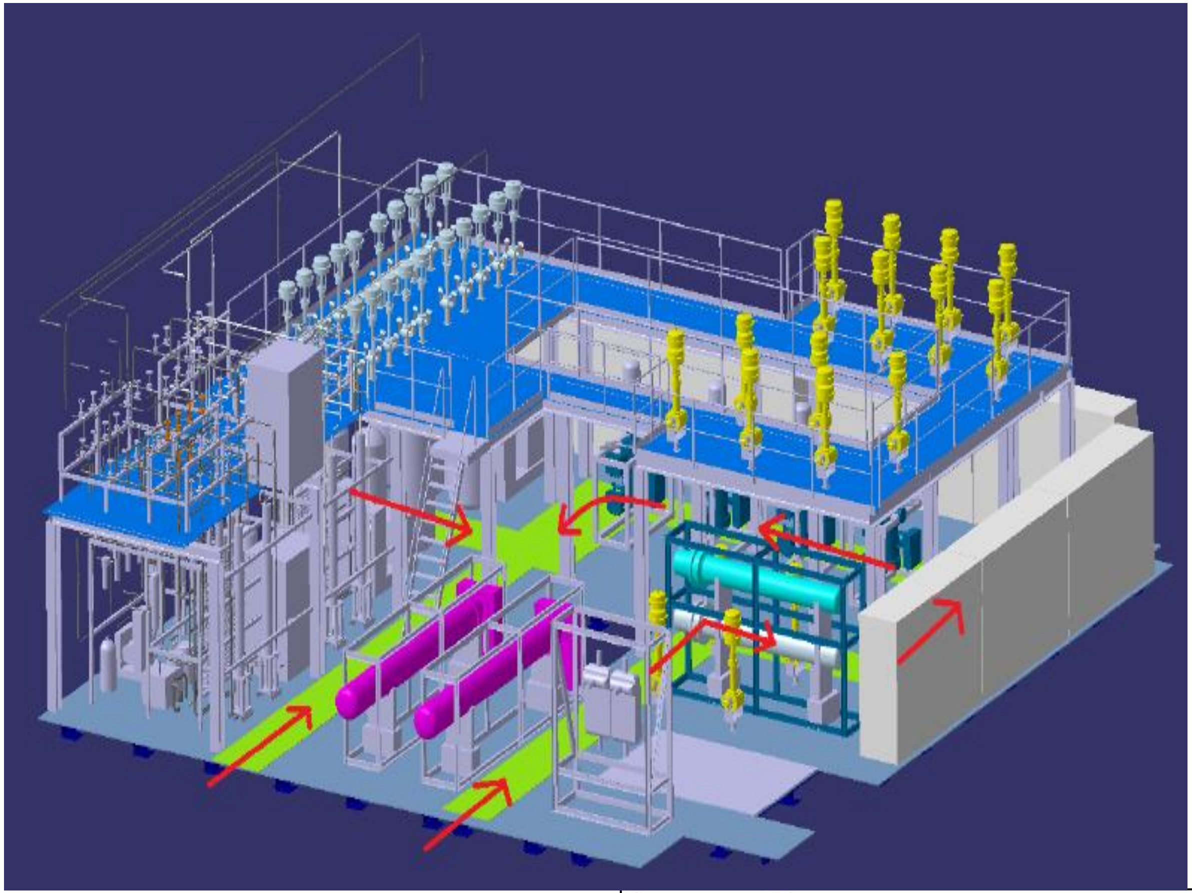
CATIA model of the IN LLCB-HCS (+CPS)

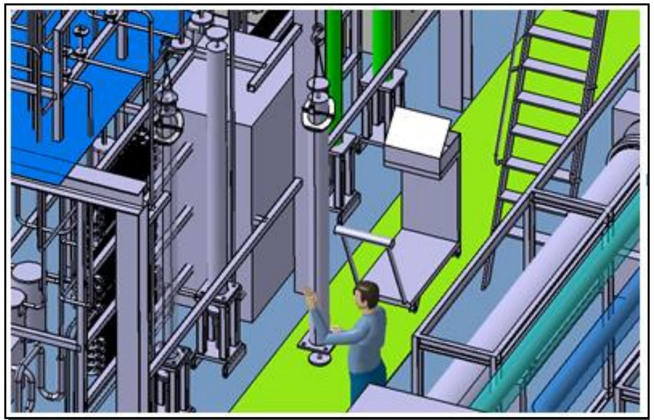
IPR, India



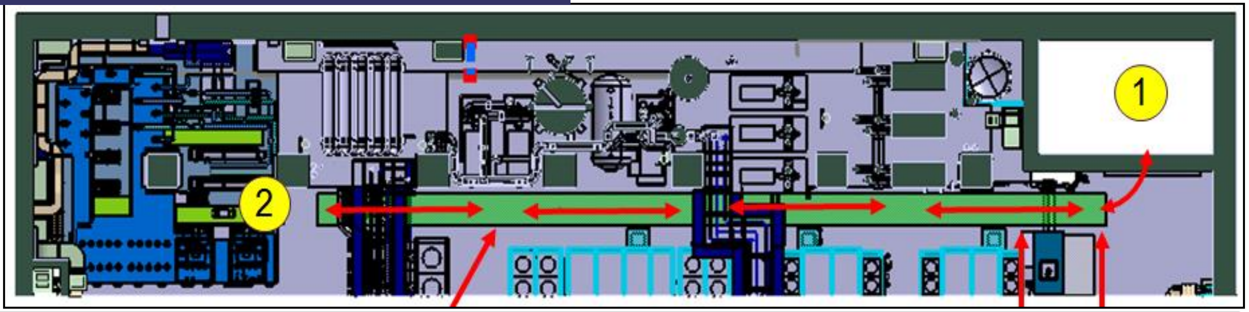
The design & development of Helium Cooling Systems (both FWHCS and LLHCS) will be supported by R&D activities in a similar experimental facility, i.e. Experimental Helium Cooling Loop (EHCL) which will be installed in IPR, India.

CATIA model of the EU HCLL & HCPB HCS (+CPS)





(1) Cargo Lift for installation & maintenance
(2) Components drop area from the crane



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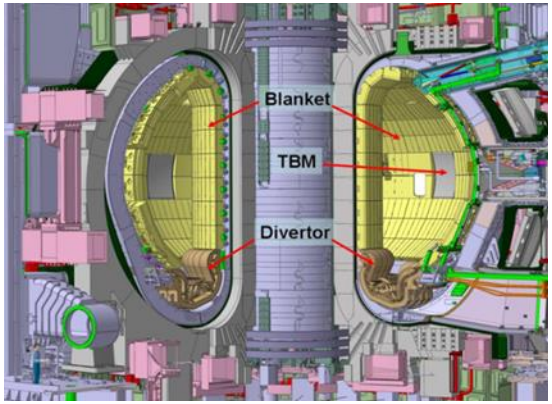
Example of Testing Loops for the EU HCLL HCS

HCS loop "He-FUS 3" coupled with the PbLi loop "IELLLO" – EBBTF (ENEA-Brasimone) – TBM as coupling element

IELLLO Operative Conditions
- Processed fluid: Pb-16Li
- Design Temperature: 550°C
- Design Pressure: 0.5 MPa
- Max LM flow rate: 3.0 kg/s
- LM Inventory: 500 l
- Max Heating Power: 60 kW

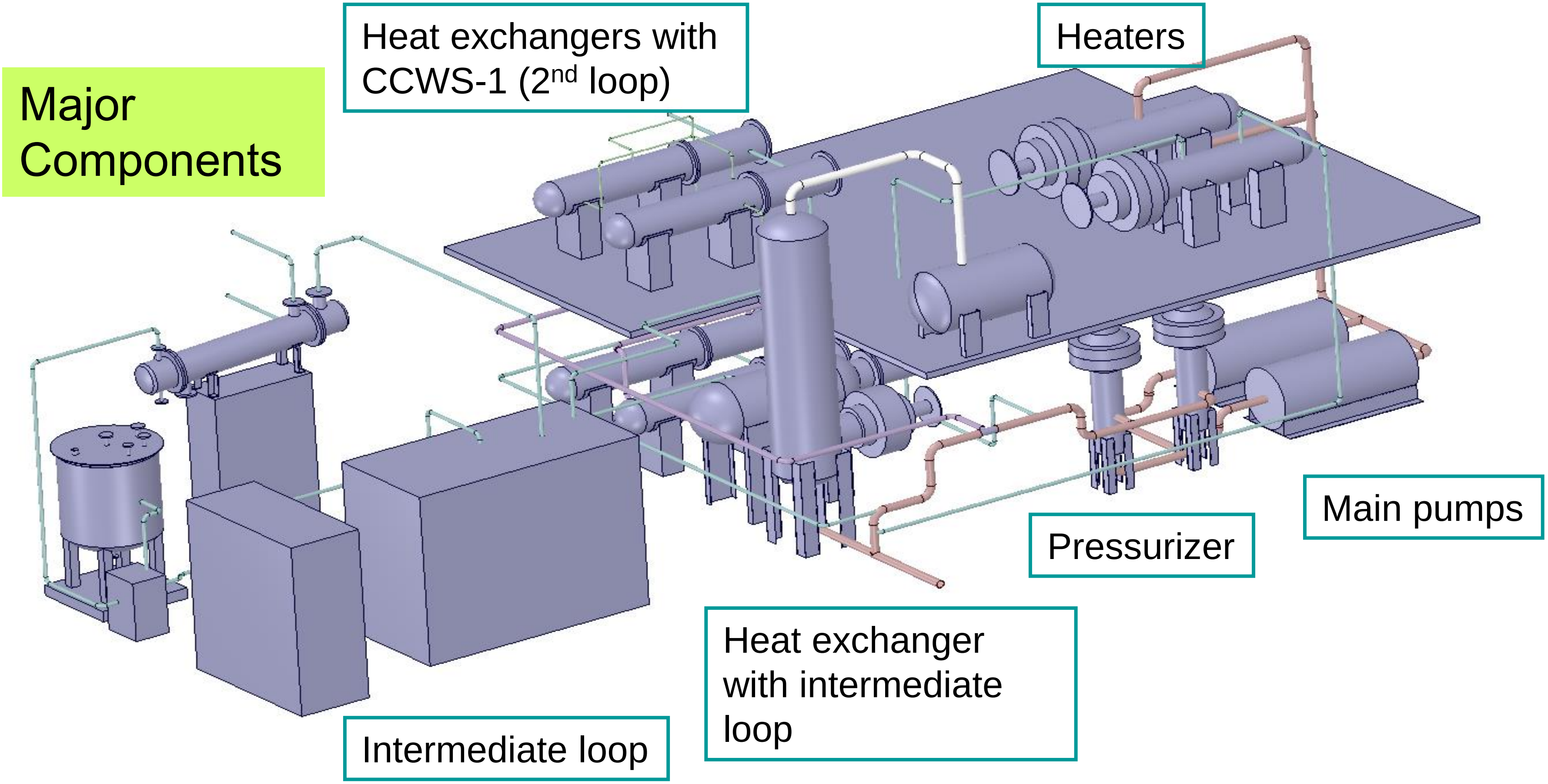
He-Fus 3 Operative Conditions
- Processed fluid: He
- Design Temperature: 530 °C
- Design Pressure: 8 MPa
- Max He mass flow-rate: 0.35 kg/s
- Max heating power: 210 kW



5 b – Main Features of Water Coolant System

(WCCB-TBS)

Scheme/CATIA model of the WCCB WCS



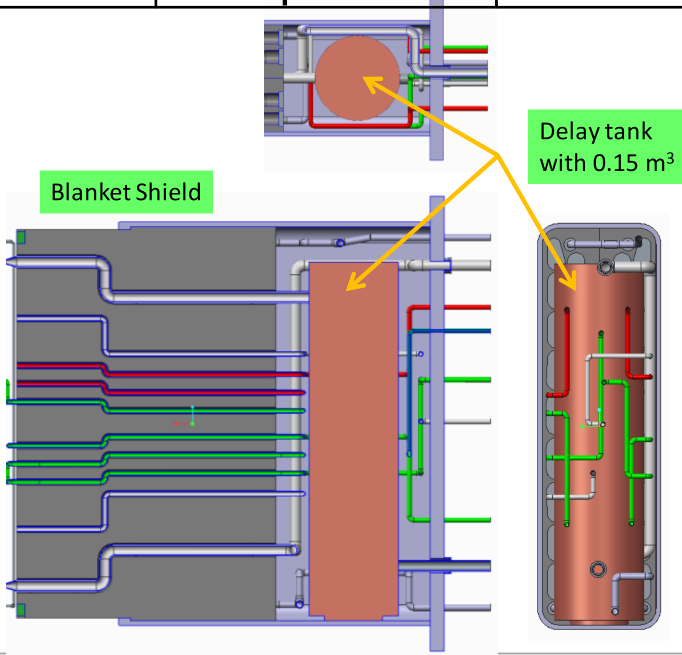
- WCS has a CPS, and it can remove ACP but not tritium.
- To avoid tritium migration to CCWS-1, an intermediate loop was added.

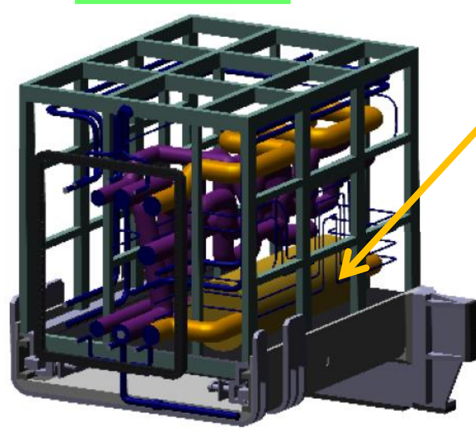
Additional Delay tanks needed for the WCCB WCS

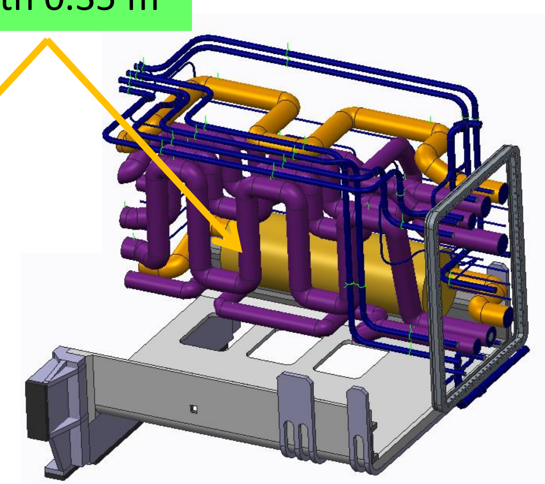
- Additional delay tanks installed in WCS to relax activities caused by ^{16}N.
- With 2 delay tanks of 500 liters, the water takes additional 80 s to reach the bio-shield, leading to a reduction of the associated dose rate on electronics in Port Cell and beyond of more than a factor 2000.

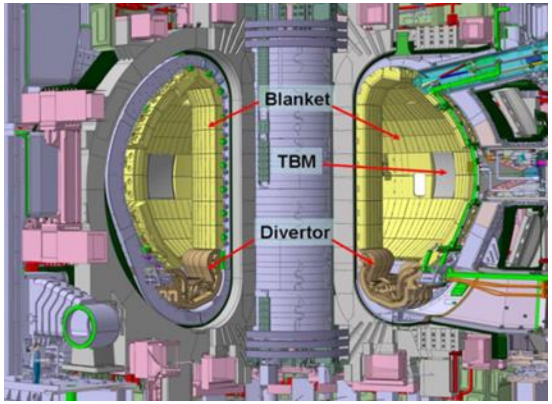
Main specifications for the delay tanks

	Location	Outer diameter	Wall thickness	Length	Capacity	Weight
Tank 1	in TBM Shield	0.43 m	35 mm	1.5 m	0.15 m^3	1000 kg
Tank 2	in Pipe forest	0.6 m	48 mm	1.8 m	0.35 m^3	2600 kg



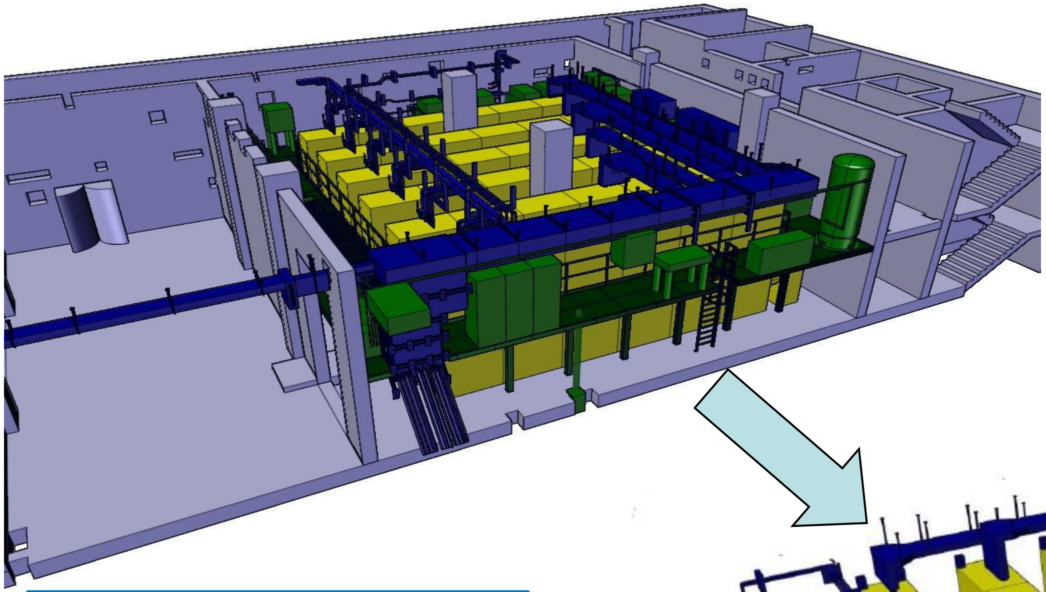




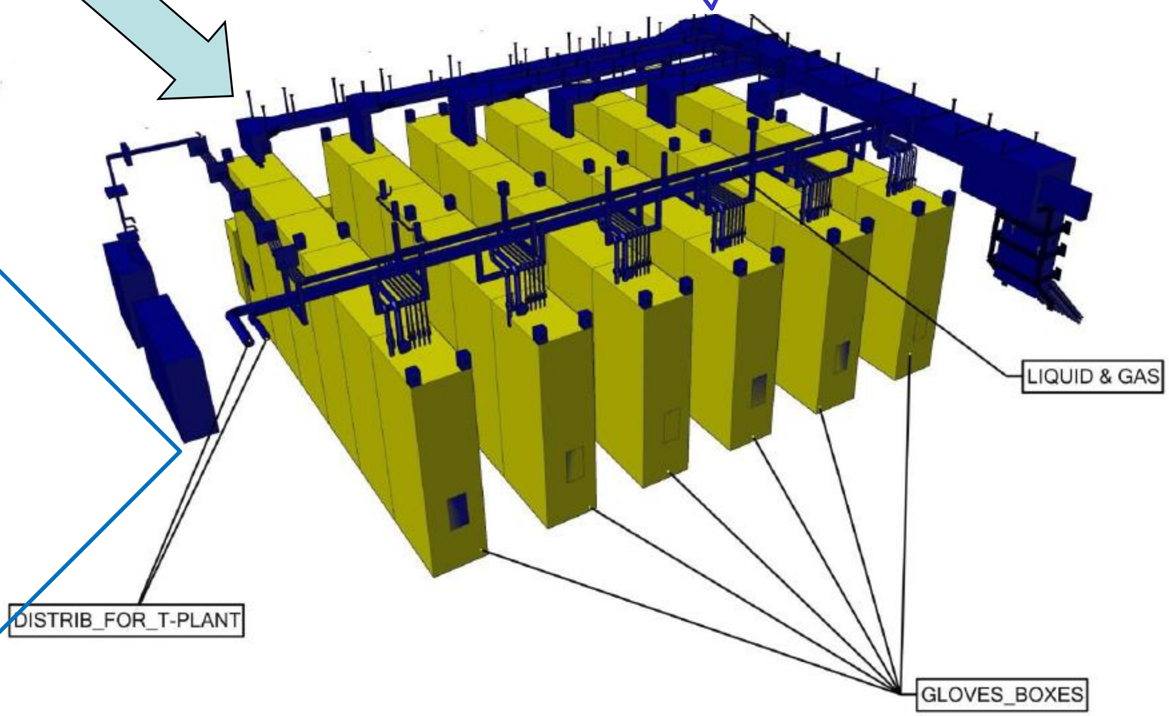


5 c – Main Features of some Tritium Extraction Systems
(Applicable to HCLL, HCPB, WCCB, HCCR, HCCB, LLCB TBSs)

Layout of the 6 TBSs Glove Boxes in the Process Room



Pipes for T-Extraction,
T-Accountancy and Neutron
Activation Systems
Fire Protection

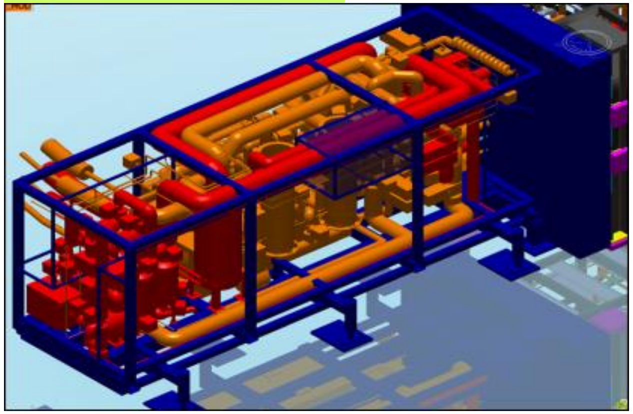


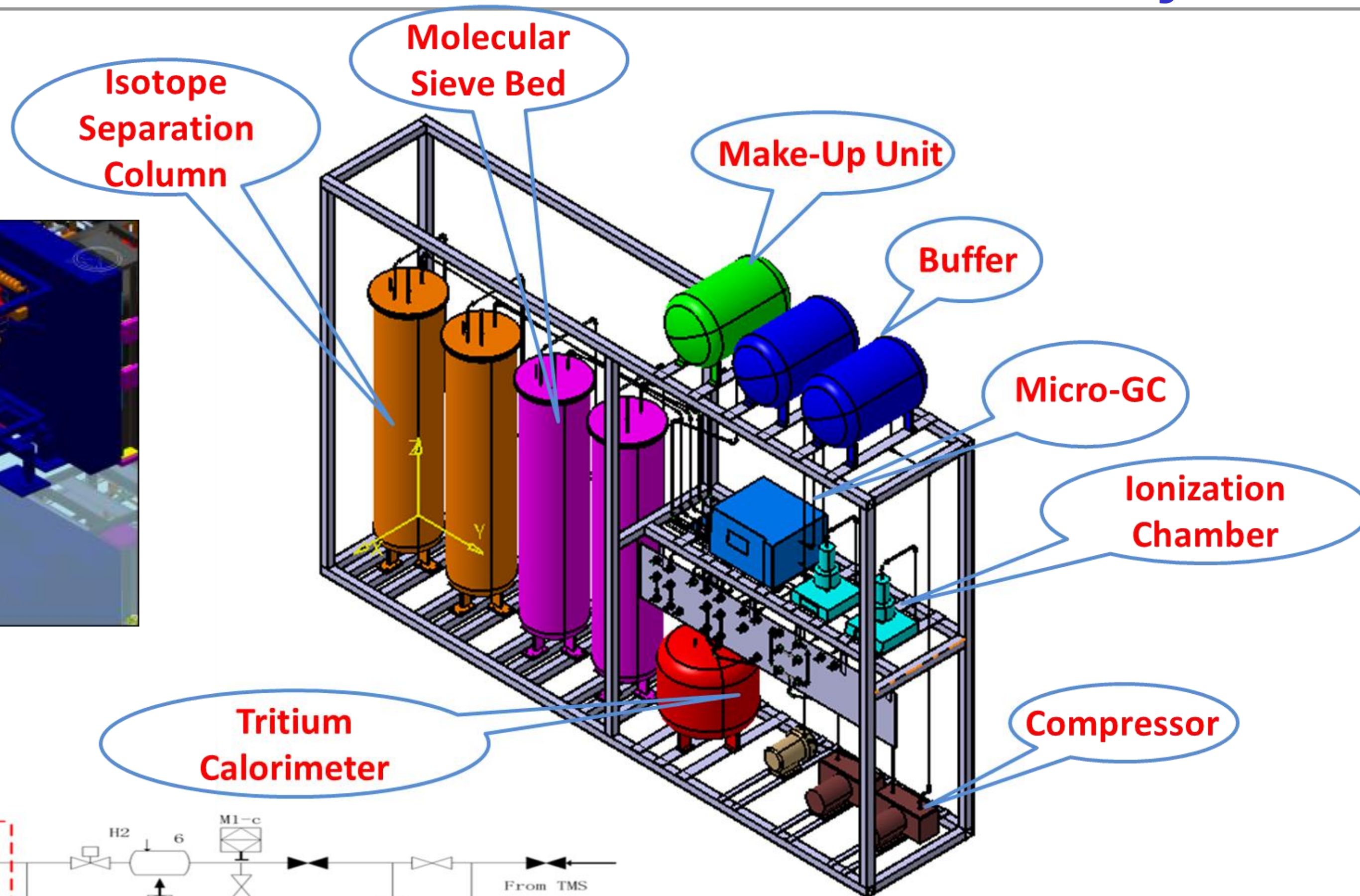
Main connections needed to operate each TES:

- with Detritiation System
- with Tokamak Exhaust Processing
- with L/G Nitrogen, He, compressed air services
- with Power Supply
- with H-Supply

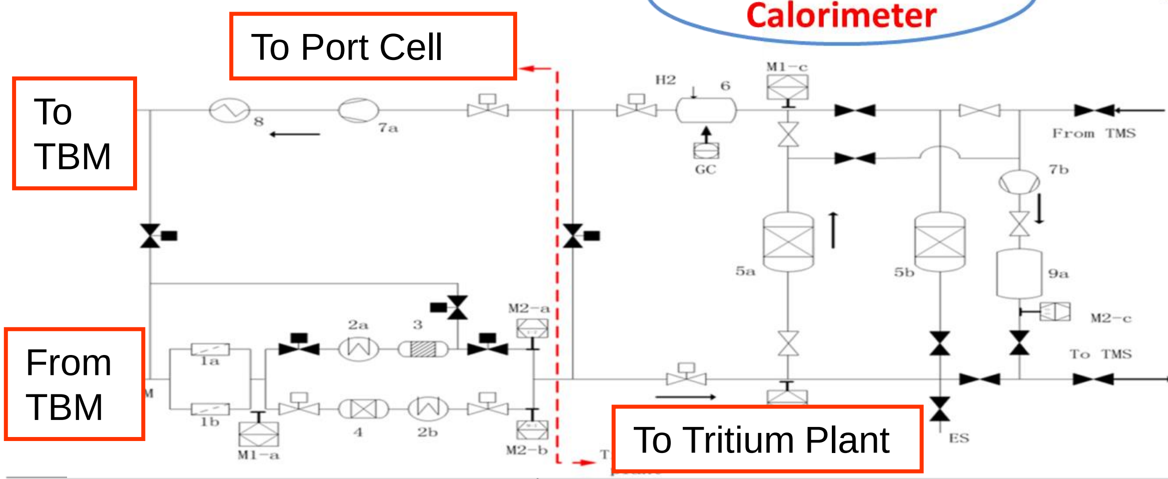
Main Components for the CN-HCCB Tritium Extraction System

In the AEU

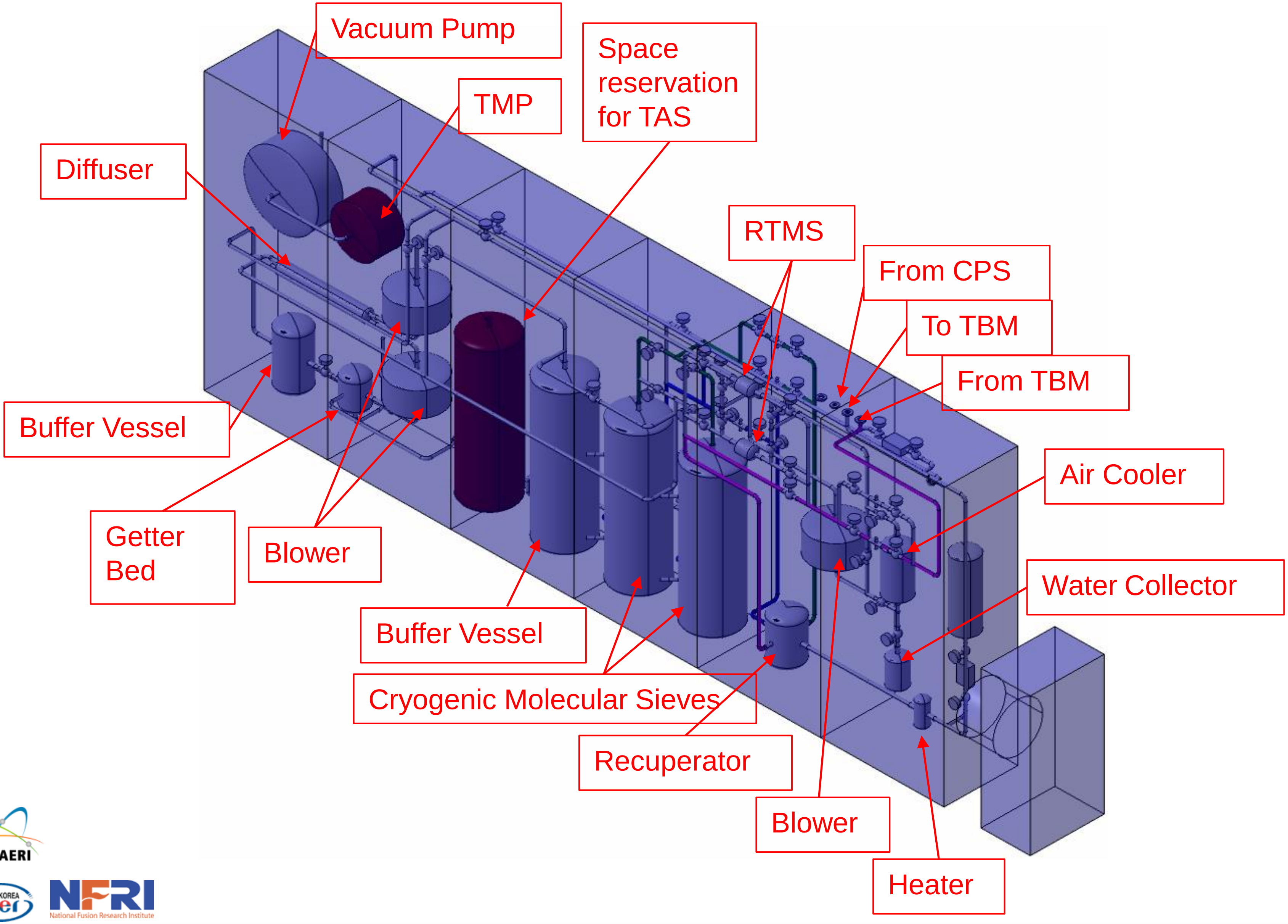


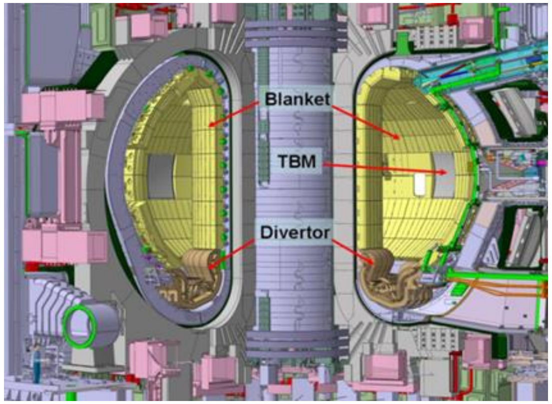


In the Glove Box In Tritium Building



Main Components inside the KO-HCCR-TBS Glove Box





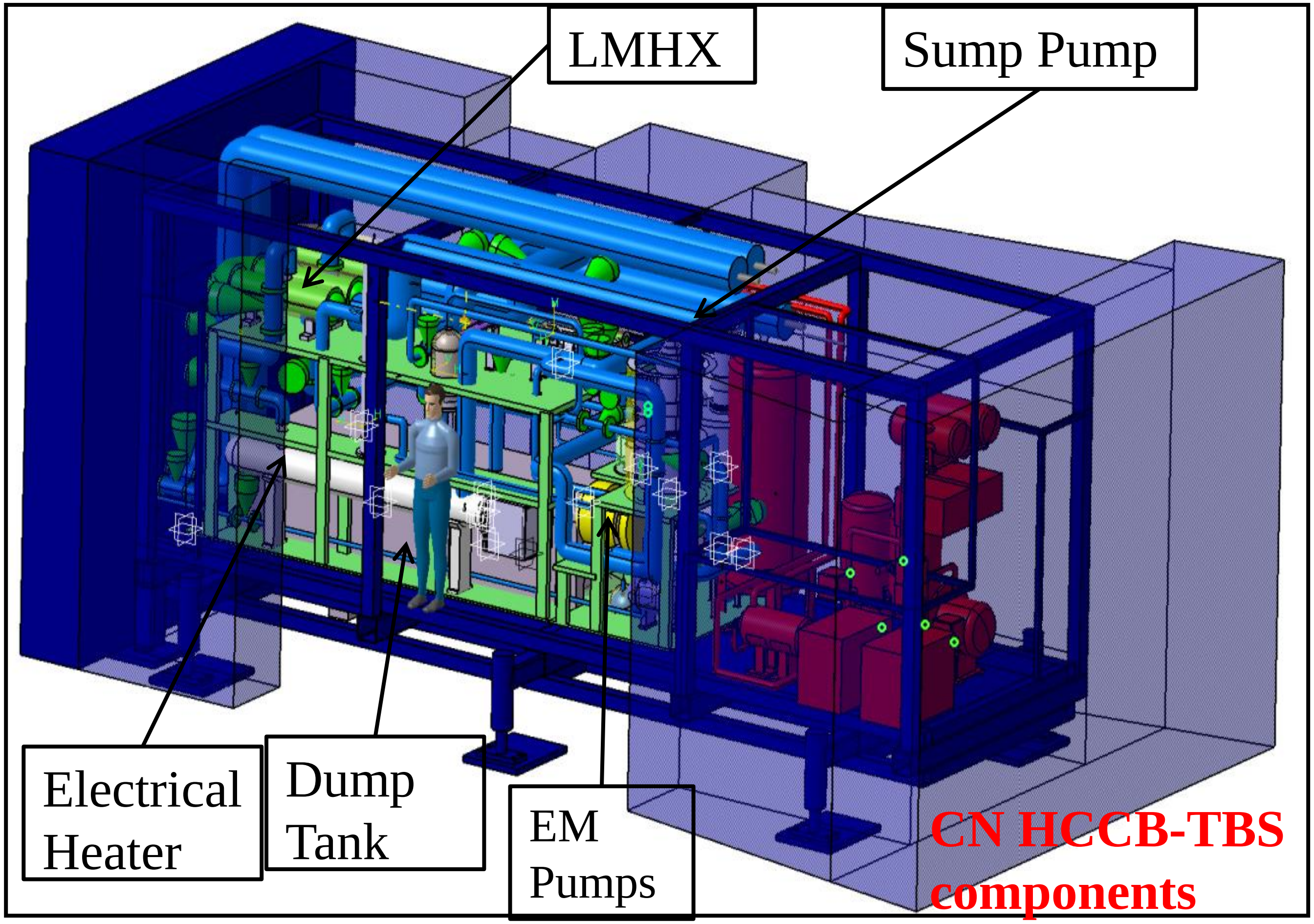
5 d – Main Features of Lithium-Lead Systems

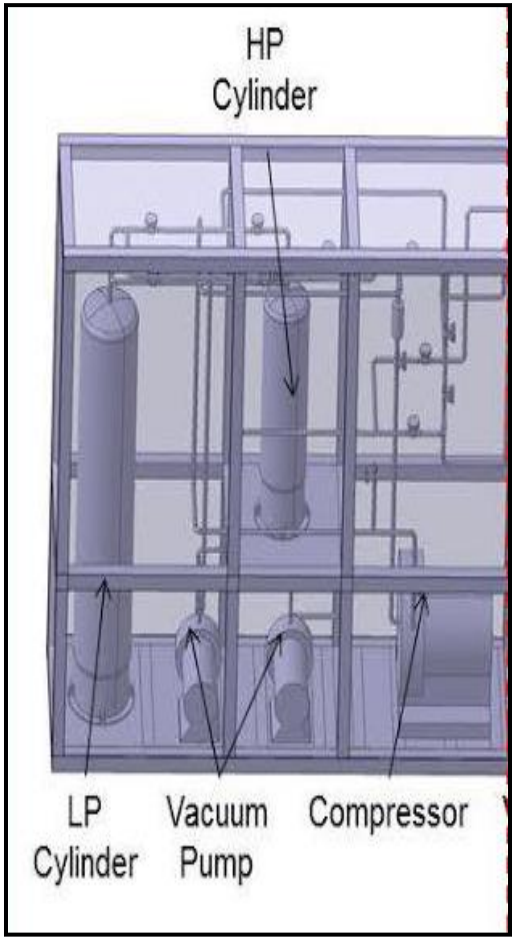
(Applicable to LLCB TBS and, partially to HCLL-TBS since Pb-16Li is not used as coolant)

CATIA model of the LLCB Pb-16Li cooling system

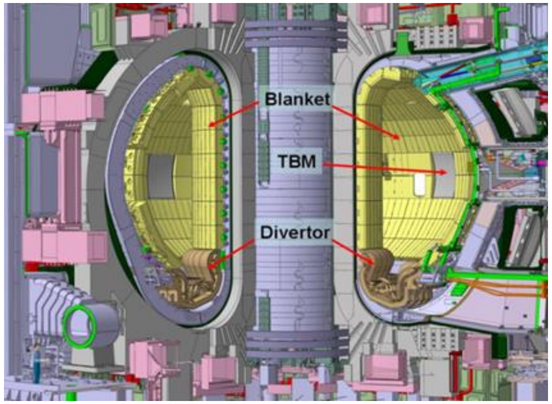
IPR, India

Molten Pb-16Li provides cooling of the TBM breeder zone (380 kW) and Tritium breeding and neutron multiplication





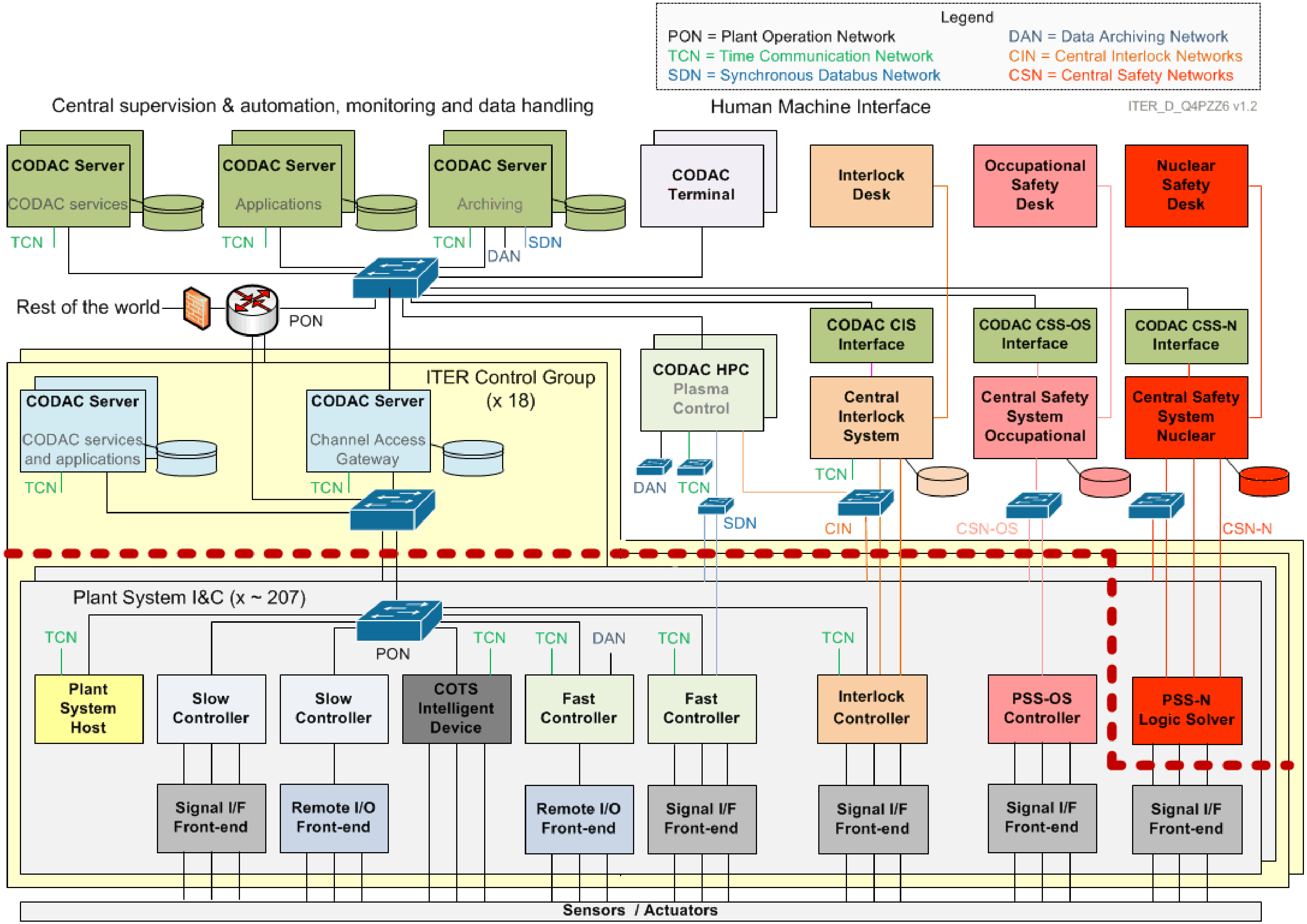
Pb-Li cover gas system components in Tritium building



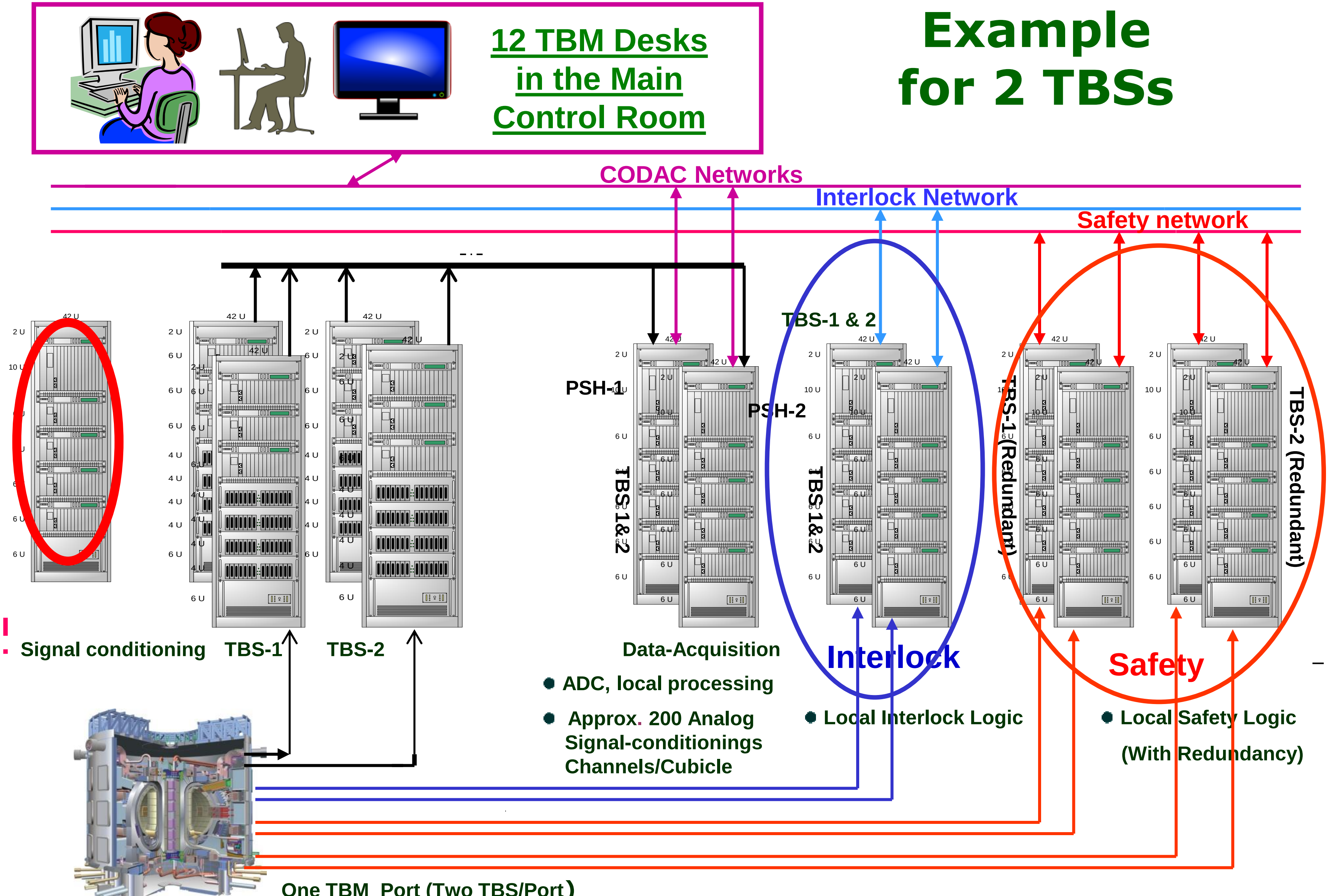
5 e – Main Features of Instrumentation & Control Systems

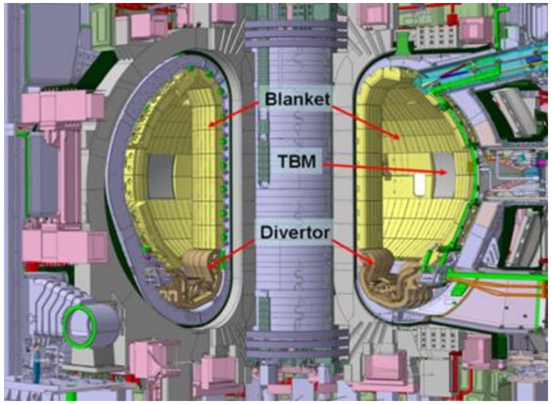
(HCLL, HCPB, WCCB, HCCR, HCCB, LLCB TBSs)

Summary of Scope and Architecture of ITER I&C Network



Specific interfaces with Test Blanket Systems





6 – Summary of the Main TBS Interfaces with other ITER Systems

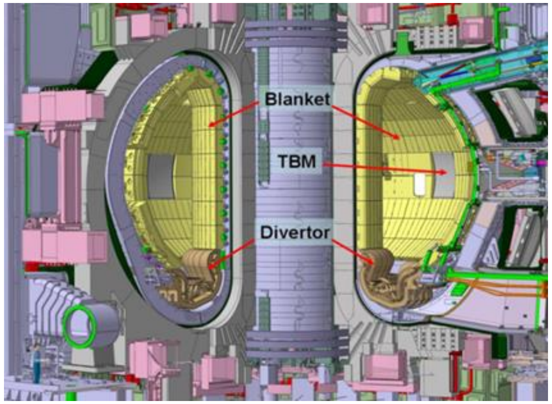
(HCLL, HCPB, WCCB, HCCR, HCCB, LLCB TBSs)

Interfaces with >20 other ITER Systems/Activities *(1/2)*

Interface	TBS requirements and impacts on TBS features/performance
Vacuum Vessel	TBM port plug attachment to the VV port extension – Limitation in the PP weight – Capability to withstand EM induced forces
Machine Assembly	Identification of all assembly and installation needs, definition of TBS specific tooling (including for TBS components handling)
Remote Handling	Need to use transfer casks for each TBM port plug replacement – Limitation in PP weight
ITER cooling water system (2)	Need of primary cooling for TBM frames implying pressure drop control – Need of secondary water cooling for TBS, only limited Tritium permeation is acceptable (both operations and accidents)
Tritium Plant	Limitation on Tritium losses in Tokamak building – need to control the compositions and the flowrate of tritiated gases sent to the plant
Electrical power network	Definition of the required power to be used for operating the TBSs – several MWs of installed power are required – issue of LV circulator against MV supply needs to be solved
Cables Trays System	Definition of the quantity cables associated to measurements and related cubicles (far from magnetic field) – limited space available, optimization/reduction of number of sensors

Interfaces with >20 other ITER Systems/Activities *(2/2)*

Interface	TBS requirements and impacts on TBS features/performance
CODAC, Central Interlock System & Central Safety System	TBSs operated from the Control Room via CODAC – Actions on other systems (such as plasma shutdown request) to ensure either safety or investment protection made by CSS & CIS – identification of few keys measurements (e.g., P, flow-rate)
Plasma Control	Need of plasma shutdown in case of loss-of-coolant/flow events
Port Plug Test Facility (PPTF)	Used to detect potential leaks in TBM Port Plugs before installation
Nuclear buildings (3)	Definition of supporting plates, openings (tight when crossing different fire and/or contamination zoning), components weight – Local Air Coolers, nuclear buildings in construction ➔ constraints
Liquid and Gas distribution (4)	TBS operations need compressed air (for valves), Helium, demineralized water, Nitrogen (for T-extraction process)
Radiological protection	Need to define maximum acceptable T-losses to reduce T-concentration in accessible rooms (otherwise alarm is activated)
Rad-waste treatment and storage (Hot Cell)	TBSs operations produce rad-waste that need to be treated and stored – some TBS materials are not present in ITER ➔ special treatments might be required – TBM shipping to ITER Members



7 – Final Considerations and Conclusions

Components Classifications

- ITER has been defined as a French Nuclear Facility (INB-174). This has a strong impact on the TBS components design, manufacturing, installation and operations. It is the first fusion facility falling under this definition.
- Each TBS features between 60 and 90 components (excluding I&C systems). Therefore, for the six TBSs there are in **total more than 500 components** (excluding I&C systems) located in various rooms of the Tokamak Complex buildings. Each component has its own classifications.
- Main component classifications are the following:
  - Protection Important Component (PIC)
  - ESP/ESPN (Pressure Equipment / Nuclear Pressure Equipment)
  - Quality class
  - Seismic, Tritium, Remote Handling
- Each classification has an impact on the required design and fabrication procedure, on the component credit for safety assessment, on the installation/inspection procedure, on cost, on acceptance tests, etc…
- The classification of each component has therefore to be fully defined and agreed by the IO-CT as Nuclear Operator, before finalising the design and starting the procurements

Status and Schedule Aspects

Main TBM Program milestones:

(the various Test Blanket Systems and associated infrastructures have slightly different planning; however, in all cases the final delivery is planned for Assembly Phase III)

- Conceptual Design: **completed and approved for all components**
- Preliminary Design: reviews spread over 2018-2022
- Final Design: reviews spread over 2021-2024
- Manufacturing: plan to start after 2023
- Delivery on ITER Site 2029, installation starts in 2030
- Special case for TBS Connection Pipes: Final Design review in early 2019, manufacturing starts in 2019, delivery/installation in 2020-22.

Conclusions

- All the six Test Blanket Systems and components (including infrastructures) has now passed the Conceptual Design Phase.
- All the presented CATIA models and the associated Process Flow Diagrams and Piping and Instrumentation Diagrams are also defined at Conceptual Level.
- Many other ITER Systems are in a more advanced stage and, therefore, their interfaces with the Test Blanket Systems are frozen.
- The Preliminary Design Phase has started and is expected to be completed in the next 2-4 years (depending of the TBS).
- The only exception is for the TBS Connection Pipes since, because they are captive components, they are already in the Final Stage with manufacturing starting in 2019.

Thank you for your attention